

AERO DIGEST

INCLUDING
AVIATION ENGINEERING

JULY 1954

progress of missile science

THIS ISSUE \$1.00



more muscle for the missile

The LO-U/c* Turbine—Another remarkable Hydro-Aire development that promises greatly improved power handling for both Rockets and Ram-jets

Some time ago Hydro-Aire successfully developed a revolutionary new fuel booster pump called the HY-V/L.†

Now Hydro-Aire's Turbo-Machinery program has come up with a new class of low-speed, high-pressure turbines...lighter, more compact, and highly reliable in operation. The design is well-suited to low-cost quantity production and eliminates all complex controls.

Each of these two developments is an outstanding achievement in its own right. But the whole is greater than the sum of its parts; and the combination of the HY-V/L Pump with the LO-U/c Turbine has resulted in a very remarkably advanced Turbine-driven Fuel Pump. There are some particularly effective applications for anyone concerned with Primary Pumping Plants for Missiles.

Just another example of Hydro-Aire's creative engineering and production know-how that is solving missile power problems in virtually every category: from fuel systems to electronics.

HYDRO-AIRE Inc.
3000 WINONA AVENUE, BURBANK, CALIFORNIA
Subsidiary of Crane Co.

*Low speed/high pressure head

†High vapor/liquid ratio

EVERY FIGHTER, EVERY BOMBER, EVERY TRANSPORT IS HYDRO-AIRE EQUIPPED



HAMILTON STANDARD . . . leader for years in propeller design and production, is supplying other equipment for such outstanding new jet aircraft as the Air Force's Convair F-102, interceptor-fighter.

Wherever Man Flies



Propellers • Starters • Air Conditioning • Fuel Controls • Pneumatic Valves • Hydraulic Pumps
 HAMILTON STANDARD, WINDSOR LOCKS, CONNECTICUT

SAFETY by *Swedlow*

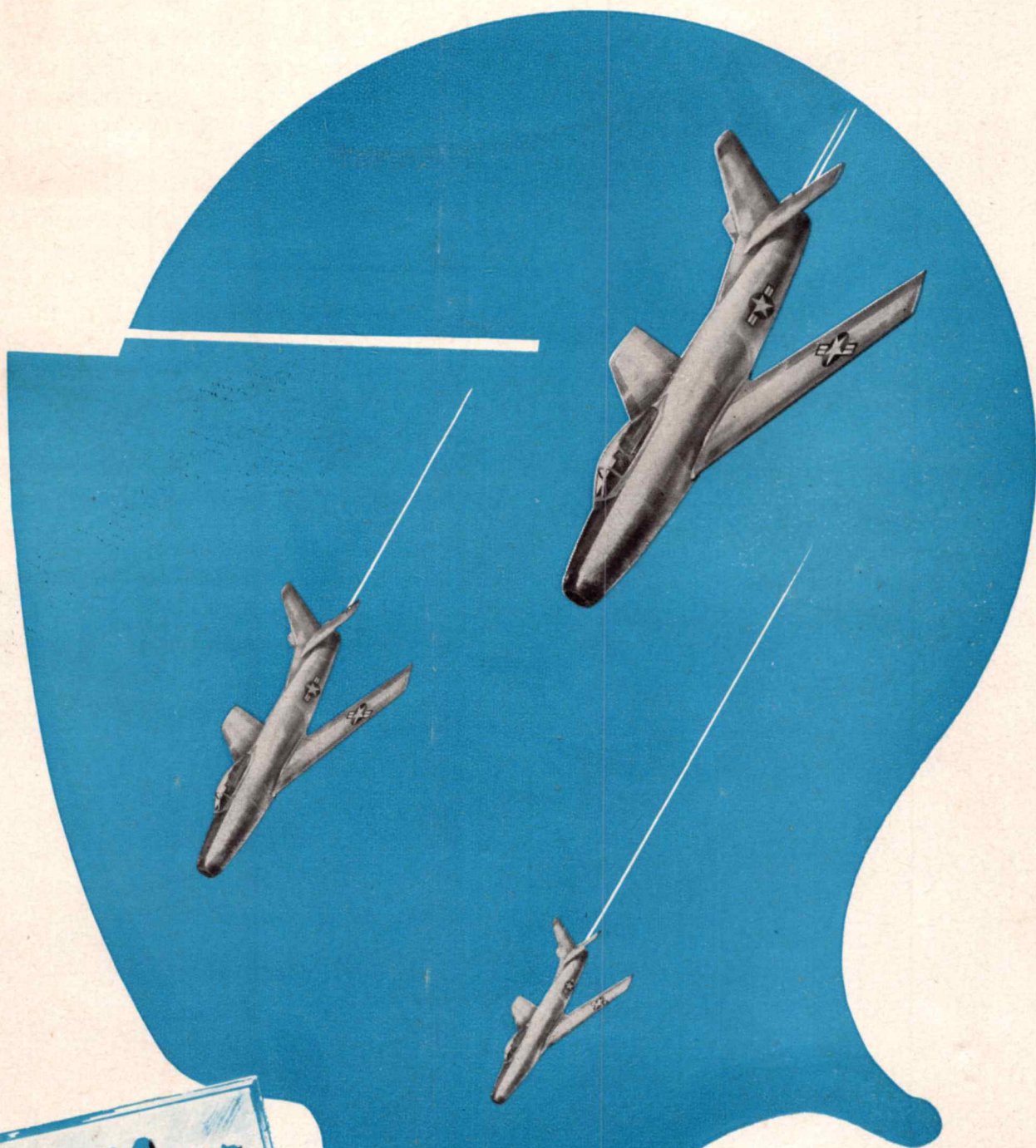
From "Knights of the Round Table" to the twentieth century "Knights of the Air" who do their jousting at supersonic speeds, armor has been a factor of safety in combat that cut casualties to a notable degree.

Swedlon Laminate XIG-112, approved under MIL. Spec. A-17856 (Aer) Armor fragm. non-metallic, protects the pilot

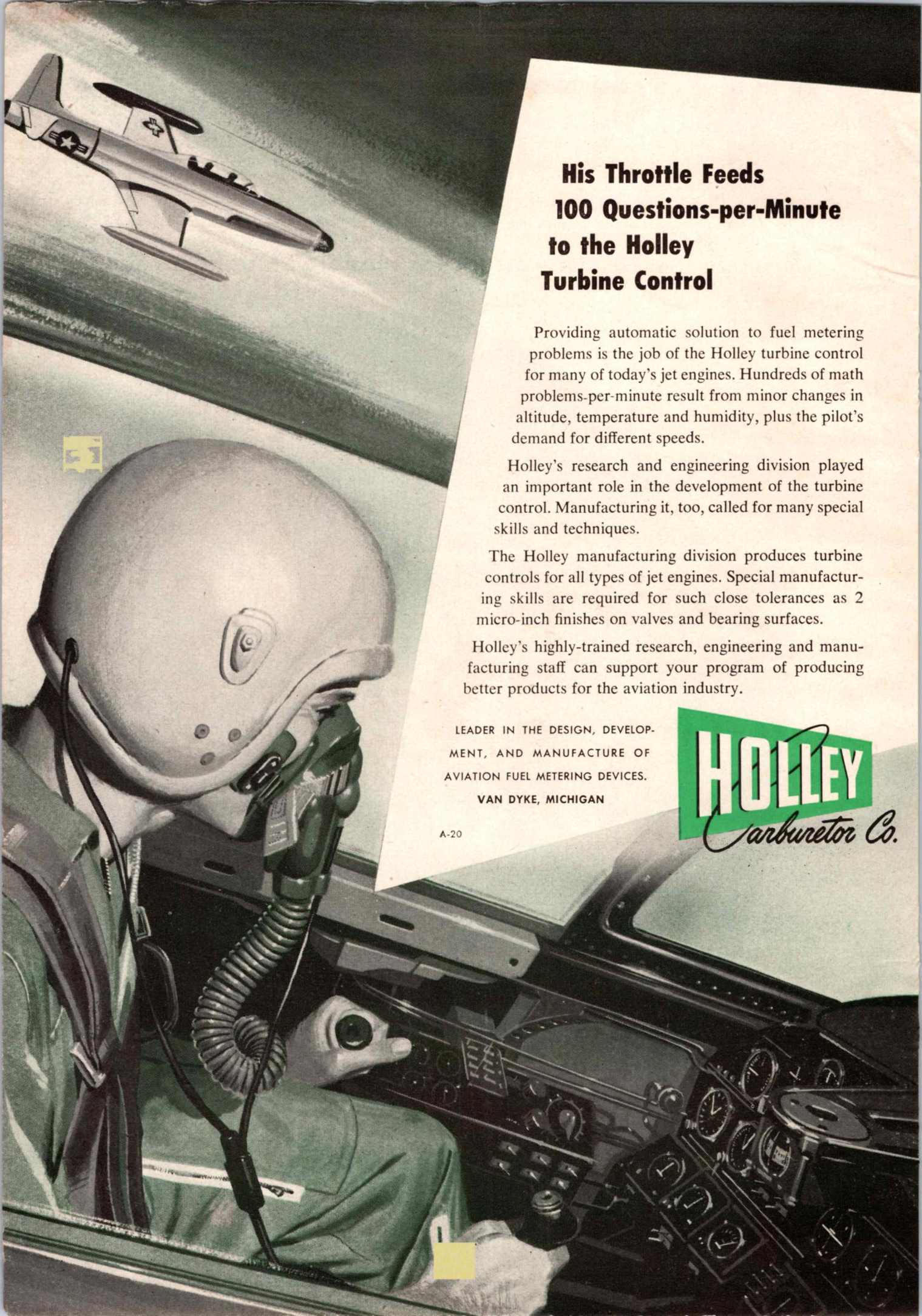
at the most vulnerable points of the cockpit—on the floor, as protection against flak—in the backrest, as protection from bullets—and as protection for the vital electronic controls.

For information on this and other Swedlon laminate applications, contact the Swedlow plant nearest to you.

SWEDLON—armor for modern "knights of the air"



LOS ANGELES, CALIFORNIA • YOUNGSTOWN, OHIO



His Throttle Feeds 100 Questions-per-Minute to the Holley Turbine Control

Providing automatic solution to fuel metering problems is the job of the Holley turbine control for many of today's jet engines. Hundreds of math problems-per-minute result from minor changes in altitude, temperature and humidity, plus the pilot's demand for different speeds.

Holley's research and engineering division played an important role in the development of the turbine control. Manufacturing it, too, called for many special skills and techniques.

The Holley manufacturing division produces turbine controls for all types of jet engines. Special manufacturing skills are required for such close tolerances as 2 micro-inch finishes on valves and bearing surfaces.

Holley's highly-trained research, engineering and manufacturing staff can support your program of producing better products for the aviation industry.

LEADER IN THE DESIGN, DEVELOPMENT, AND MANUFACTURE OF
AVIATION FUEL METERING DEVICES.
VAN DYKE, MICHIGAN

A-20

HOLLEY
Carburetor Co.

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See page 14 for acknowledgments

DURANICKEL

may easily provide the
spring properties
you need in a
corrosion-resisting alloy!

You might look a long time before finding another alloy with all the advantages of Duranickel.

A wrought alloy, Duranickel is age-hardenable, or capable of having its hardness and strength increased by thermal treatment—and has the dependable corrosion resistance of Nickel.

And that's only the beginning! You can figure for yourself just how valuable Duranickel could be for a spring application of yours when you consider its other principal characteristics:

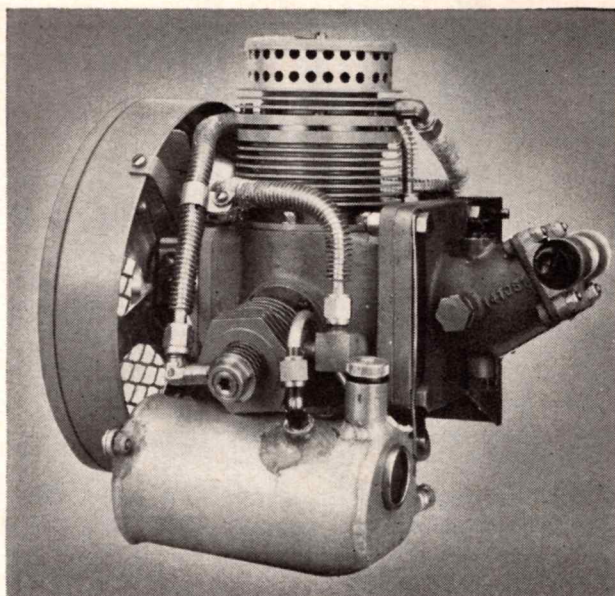
- uniform spring properties at temperatures up to 600° F.
- high fatigue strength and endurance limit for non-ferrous, corrosion-resisting materials
- ready workability

As a typical example of Duranickel's usefulness, let's examine briefly the new Kidde 4-stage compressor shown above.

Developed for pneumatically-operated airborne equipment, this lightweight compressor has neither connecting rods, wrist pins nor other complications required by conventional design. Instead, a crankshaft-riding cam simply pushes the pistons into their cylinders. A scotch yoke and sliding rod reverses the first piston while compressed air from preceding stages retracts the others.

Mechanical Property Ranges of Duranickel

Form and Condition	Tensile Strength 1000 psi.	Yield Strength (0.2% offset) 1000 psi.	Elongation in 2 in. per cent	Hardness Rockwell C
Rod and Bar				
Hot-finished	90-130	35-90	55-30	75B-22
Hot-finished, age-hardened	160-200	115-150	30-15	32-42
Cold-drawn, as-drawn	110-150	60-130	35-15	90B-32
Cold-drawn, age-hardened	170-210	125-175	25-15	32-42
Strip				
1/2 hard	130-155		15-3	25-34
1/2 hard, age-hardened	170-210		20-7	33-42
Spring	155-190		10-2	30-40
Spring, age-hardened	180-230		15-5	36-46
Wire				
Spring	160-200		5-2	
Spring, age-hardened	200-240		10-5	



SMALL COMPRESSOR delivers big volume at high altitudes. At 35,000 feet, this 4-stage, 4-piston air compressor delivers (from ambient pressure) one cfm of free air compressed to 3,000 psi. Its sea level delivery of 4 cfm of free air compressed to 3,000 psi can be maintained at high altitudes when inlet air is pressurized. The compressor weighs only 15 pounds, has first-stage valve of Duranickel, and Duranickel assist springs to insure closing of intake valves. Photo courtesy of Walter Kidde & Co., Inc., Belleville, N. J.

For the disc valve in the first stage which is intricately shaped and then heat treated, the design engineers of Walter Kidde & Company, Inc., specified age-hardenable Duranickel. They also called for Duranickel for valve assist springs.

Duranickel is well able to withstand the high temperatures encountered in meeting the severe requirements. It is not affected by moisture squeezed out of the air during compression. And it offers high strength to prevent warpage.

Put Duranickel down in your book for *workability*, too. It can be hot-worked, forged and cold-worked.

It is most readily machined in the annealed condition, and is commercially machinable in other conditions at hardnesses up to 275 BHN.

Duranickel can be joined by commonly-used welding, brazing and soft soldering processes, including inert gas metal arc welding.

You'll find detailed engineering data on Duranickel (and its companion alloys, Duranickel "R" and Permanickel®) in Technical Bulletin T-32, "Engineering Properties of Duranickel." A copy is ready and waiting for you. Write us for it.

THE INTERNATIONAL NICKEL COMPANY, INC.

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MONEL® • "R"® MONEL • "K"® MONEL • "KR"® MONEL
"S"® MONEL • NICKEL • LOW CARBON NICKEL • DURANICKEL®
INCONEL® • INCONEL "X"® • INCONEL "W"®
INCOLOY® • NIMONIC® ALLOYS

AERO NEWS DIGEST

MAKING A GUIDED MISSILE that will work is easy, says Welcome W. Bender of The Glenn L. Martin Company (Page 22). All you have to do is build a device as accurate as a golfer who shoots holes-in-one time after time after time. Such a feat, if our game is an index, is patently impossible. Yet, as this special Missile Science issue of AERO DIGEST reports, it is a feat that is being performed regularly these days. The Aircraft Industries Association says that at least 44 major U. S. industrial and scientific organizations are working at guided missile prime contracts, and production is under way on at least 18 missiles.

* * *

A PIONEER IN EDITORIAL coverage of Missile Science, and the first magazine to devote an entire issue to the subject, AERO DIGEST salutes this defense program with special pride. Producing guided missiles is an infant industry in the defense program. First large-scale production orders for guided missiles were placed only two years ago. Yet making guided missiles is today a billion-dollar program. We will continue to strive toward reporting missile news to our readers first and fully. We hope that this newest of sciences will so strengthen our defenses that no enemy will dare attack. And in the meantime, we wish Mr. Bender would devote his week-ends to the hole-in-one problem. Excellent as we like to think our golf is, we could use a guided golf ball—time after time after time.

* * *

BY-PRODUCTS • If guided missiles and aeronautical research generally weren't moving so fast that it is difficult for use to keep up with them, we could devote another entire issue to by-products. Hundreds of peace-time and non-aviation developments are being

sparked by the men whose chief interests have nothing to do with earthbound problems. From the West Coast, we learn that Aerojet-General Corporation, turned up recently with an electronic device which is being tried out successfully as an anti-thieving alarm along—of all things—oil pipelines in Arabia. More significant, if not revolutionary, is the recent and unnoted discovery of a successful method of converting light into electrical energy by the Wright Air Development Center of the Air Force Air Research and Development Command. Don't look now—this one is just out of the research stage—but it may result in light-powered generating equipment capable of servicing your house—if not entire communities.

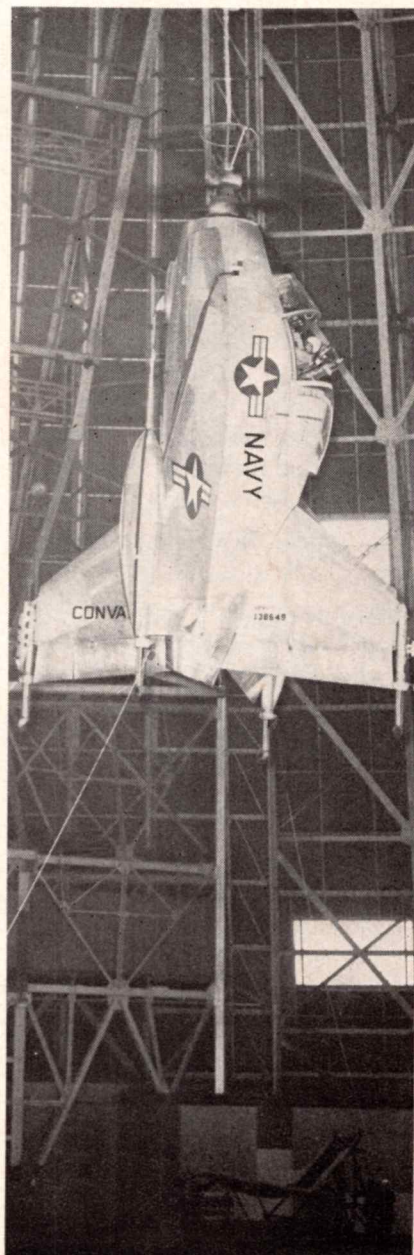
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POWERFUL PAINT POWDER • ARDC already has in operation a miniature generator powerful enough to run a clock. Increased size and further development may make it possible to step up voltage to unlimited quantities, the researchers report. Conversion powers of the generator are so great that a wafer-thin slab of crystal, 4 x 15 ft., either resting on or built into the roof of a house, will supply enough current to operate all its lights, stove, refrigerator and other appliances around the clock. Secret is in the use of cadmium sulfide, a yellow powder used as a pigment in paint, which when processed into crystal form permits a direct conversion of light into electrical impulses. The crystal in the clock-powering model is about the size of a sugar cube, but it need only be wafer thin to work efficiently. Attached to opposite sides of the crystals are electrodes, or terminals. One, made of silver, is the positive electrode. The negative is indium. A wire from the positive electrode runs to a motor or battery and back to the negative to form a circuit. It's that simple.

* * *

CEILING UNLIMITED • In the pilot model of the barrier layer cell, a one-eighth sq. in. area produces one-third volt. Improvements are expected to increase this voltage six to eight times. Increase the area of electrode attached to the crystal, and you increase voltage proportionately. Donald C. Rey-

Convair XFY-1 vertical take off fighter makes historic first vertical flight in dirigible hanger at Moffett Field, Calif.



3 Challenges

to your imagination

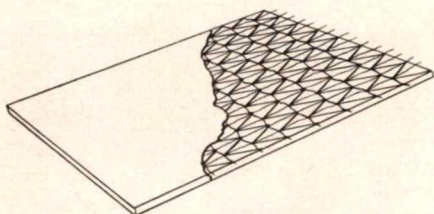
Here are 3 fabulous new materials

HOW MANY WAYS CAN YOU USE THEM?

New problems in a world of new developments call for new materials, so Goodyear has developed 3 new industrial fabrics. Now they can be made available to designers and manufacturers for commercial use.

Chances are their unusual characteristics can answer vexing problems of design which have had you stumped up until now.

Let us tell you about these 3 new materials:



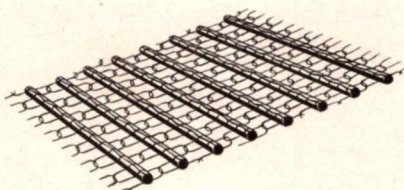
1

A FABRIC THAT CAN "BREAK"

and still retain its rated strength!

New "Double Break" Fabric For Applications Calling For Greater Shock- And Energy-Absorption, Increased Safety Factor.

This unique NEW rubberized fabric contains "shock threads" which snap upon absorbing a predetermined load — arresting damage — leaving base fabric unruptured and unimpaired. Possible uses: crash-proof fuel tanks; safety belts; shaping curved, laminated plastics.



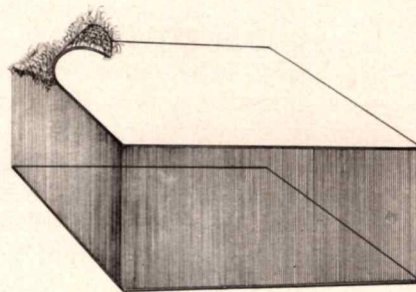
2

A FABRIC THAT CAN WITHSTAND

a ton per inch

Special High-Tensile Fabric For Construction Requiring a Flexible Material of Extreme Strength.

Feature a fabric which can take more than 2,000 pounds of tension per inch — a ton to an inch! Add to this the fact that it can be given any desired coating, and you have a high-tensile, flexible fabric — a great new aid to solving a host of design problems!



3

AN INFLATABLE FABRIC that makes like a beam!

"Air Mat"—A New Structural Material, Lightweight—Collapsible—Portable.

The double walls of this rubber-coated Nylon material are connected by thousands of rugged Nylon "hairs." The resulting "flat air" mat is capable of containing high pressures, provides excellent insulation against heat, cold and vibration — weighs only 2 pounds per square yard. Complete inflatable structures can be built of it, including beams believed to be of the highest strength-to-weight ratio known. Consequently, it is ideal for lightweight, portable scaffolding, shock cushioning, and a limitless range of structural uses.

These wonder materials are in production—yours to use now. Want to talk it over, and see how they fit into your plans? Write or wire: Goodyear, Aviation Products Division, Dept. S-1710, Akron 16, Ohio or Los Angeles 54, Calif.



FACILITIES + ABILITIES = EXTRA *plus* IN PERFORMANCE

nolds and Lieutenant Colonel Gerard M. Leies, of the Physics Research Branch at Wright, discovered the qualities of cadmium sulfide while collecting data for rectifiers. Dr. John E. Clemens, Chief of the Physics Research Branch of the laboratory, sees an unlimited ceiling for the barrier layer cell generator. It could be used to generate power at a remote air base and, in a king-sized unit, could drive motor-generators supplying electric power to an entire city.

* * *

NOTES ON THE SHOOTING WAR. Admiral Arthur W. Radford, Chairman of the Joint Chiefs of Staff, has favored air strikes in Indo-China since early spring. He is opposed by other JCS members, but supported by the White House and Secretary of State Dulles. . . . Congress might go along if allies go along with us, but England does not want to. British opposition is led by Sir Winston Churchill, who believes that if an atomic war developed out of the Indo-China situation, or elsewhere, England would be the first to suffer, if not be wiped out. He knows all too well the devastating effects of air raids, even the now-mild World War II versions. . . . Despite spring-time statements that the Russians are ahead of us in the air, the U. S. Air Force is still the best in the world, regardless of size. With or without a shooting war, the Washington consensus is that it will nevertheless be expanded and appropriations raised during the next six months in anticipation of another round of international emergencies.

* * *

LEWIS LAB • Early in June,

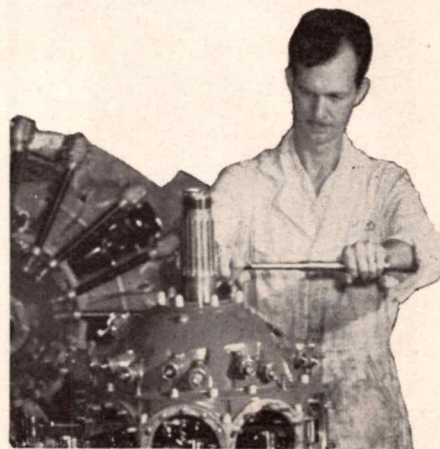
the National Advisory Committee for Aeronautics held open-house at its Lewis Flight Propulsion Laboratory in Cleveland, and another masterpiece in presenting the case for NACA resulted. While a great deal of this Lewis lab work was blanketed by security, some revealing material went on display. Notable were NACA developments in nuclear energy for aircraft, jet reversal research and developments of jet crash-fire fighting, studies on jet engine screech, and data on the reaction of metals in high-Mach-number flight. Lectures, charts and demonstrations in all departments were impeccable—in our experience, the best NACA show we have attended. We learned that security bleats from other Federal groups, notably the Atomic Energy Commission, caused confusion on the eve of the public showing, and several last-minute revisions. But there was not the slightest hint of discord when the show went on. Lewis Director Edward R. Sharp, his entire staff, the NACA leadership under Director Hugh Dryden and Executive Secretary John F. Victory, are all to be congratulated.

* * *

“EXTREME URGENCY” • NACA confirmed the AERO DIGEST survey of April, 1954, when a spokesman underlined the “extreme urgency and necessity in the development of nuclear air power.” The goal of the work underlines its vital importance: “Such an engine would make possible non-stop supersonic flight to any point on the face of the earth and return.” But NACA sees “formidable technical problems” in the way. What materials can be used to shield the engine without imperiling the crew or overloading the



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Fastest Torquer in the World!

Built-in Ratchet Head Model



After making exhaustive tests, many airlines and manufacturers of aircraft, engines and other parts standardized on the amazing PROTO Torquer for assembly and maintenance work. Some companies now use as many as 550 of this tool! In making comparative tests, they found the PROTO torque-limiting wrench to be much faster, sturdier and more accurate than other types used. They liked the automatic release, the trouble-free construction, the micrometer-type adjustment, and the lack of dials, scales and pointers — all time and money-saving features. Buy either inch-pound or foot-pound models with plain or ratchet head from your PROTO dealer. Send 10¢ for 68-page catalog to

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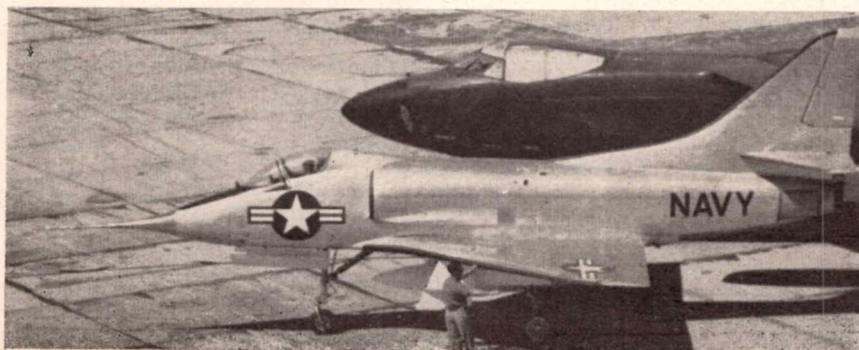
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**Head Only
of Plain
Head Model**



**Eastern Factory—Jamestown, N.Y.
Canadian Factory—London, Ont.**

World's smallest carrier bomber is this lightweight Douglas XA4D-1 Skyhawk powered by Wright J65 turbojet engine. Single-seat, delta-wing craft carries atom bomb



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Dear Sir: Please send me information on the Missile Systems Division.

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my street address _____

my city and state _____

plane is one of these. Heat transfer to supply power is another. Without being too specific, NACA reports progress. They also point out that the values of a nuclear airplane engine are almost unimaginable. A single pound of uranium, for instance, can produce as much heat as 2-million pounds of gasoline.

* * *

TURBOJET FIRES • One of the most dramatic demonstrations confirmed a statement made during the sessions by Irving Pinkel, who for some years has been doing outstanding NACA research on aircraft fire control. "Turbojet crash fires are easier to control than fires on planes powered with reciprocal engines," he states. After a crash, Pinkel found, the turbojet's compressor and turbine continue to rotate for some time, drawing large quantities of air into the inlet. Because extensive areas of the engine remain hot, crash-spilled fuel, oil and hydraulic fluid are likely to be ignited if they come into contact with the engine outer surfaces or are sucked into the inlet. Cooling to prevent this was found feasible by direct application of water. An experimental inerting system was devised and proved successful in four full-scale tests. Water used was stored under pressure and released by crash-sensitive switches.

* * *

SCREECH • NACA is doing intensive research on the unsteady operating condition which may develop in turbojet afterburners and ramjets as the pressures and temperatures approach the high values necessary to provide the desired amount of thrust. One of these — screeching combustion — characterized by a high pitched, intense note — is being studied closely. NACA indicates that current research has reached the point where change in engine designs may eliminate this difficulty.

* * *

MELTING DIAMONDS • Along with designers and scores of other industry observers, NACA recognizes the serious problems at high speeds from aerodynamic heating. At extremely high Mach numbers, they report, temperatures reached would be enough to melt any presently-known materials — hot enough, indeed, to vaporize a



Richard F. M. Hamaker, new Chief Administrative Engineer, Bendix Aviation Corp.

diamond. Various expedients to preserve these materials from disintegrating have been suggested, including use of high-melting-point ceramic and metallic materials, water-cooling, and insulation. None would seem so far to promise a solution in the high Mach numbers, for, as NACA points out, a fighter cruising at Mach 3 would develop heat at a rate sufficient to melt a ton of ice a minute—and beyond that it really begins to get hot. Sustained speed for Mach 4 would increase the temperature to 1000 degrees F.

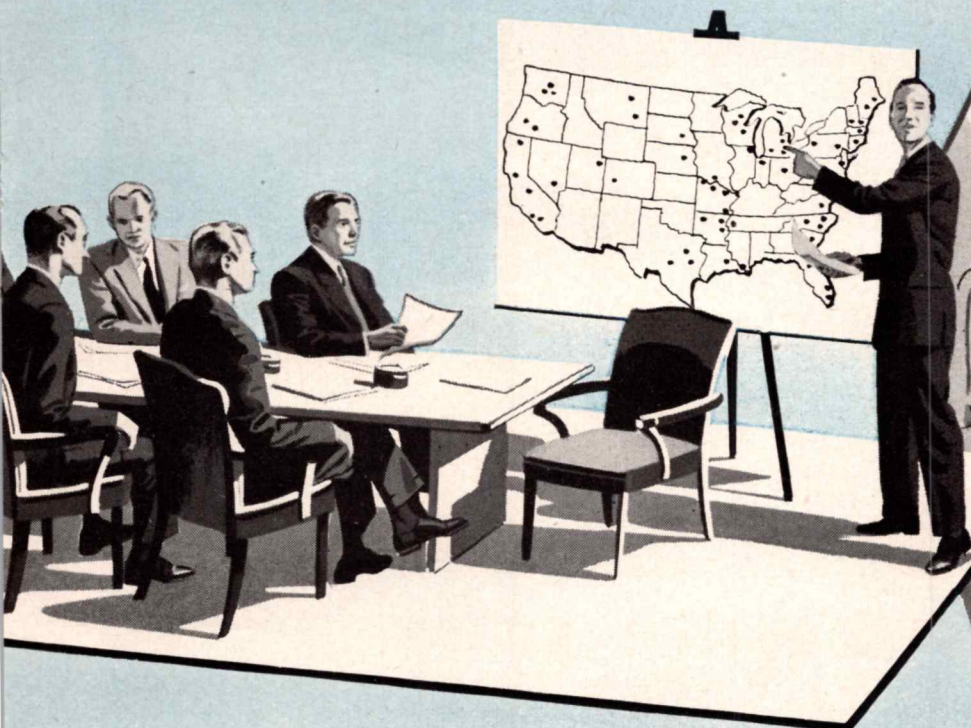
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WILLIAM P. LEAR, Board Chairman of Lear, Inc., wasn't fooling a few weeks ago when he predicted a bright future for light-planes in U. S. aviation. Now he comes up with further figures, including the optimistic statement that 80,000 corporate airplanes will be sold within the next decade. Indeed, says Mr. Lear, the corporation plane is a business machine "just like a typewriter." He foresees them selling for less than \$10,000 each, and such low-cost aircraft might mount to as many as 400,000 by 1964. How will this come about? Better instruments will make it possible, plus "full use of boundary layer control" This he sees possible within "two to five years," and once boundary layer control arrives "aviation will truly come into its own."

* * *

NAMES IN THE NEWS • Richard E. Whiffen has been pro-

How to double the efficiency of your service organization without cost



When engine builders or air frame manufacturers specify Bendix* for their fuel metering, landing gear or brake requirements, they are assured not only of the finest quality products but have at their command one of the best trained and efficient service organizations to be found in the aircraft industry.

Every member of the Bendix Products service staff has been thoroughly schooled in the latest methods of efficient maintenance procedures and is trained to work with customers from installation to ultimate replacements. Thus, the original quality and performance built into every Bendix product is delivered at all times.

Like all members of the Bendix Products

organization, the service staff is made up of men who are specialists in the fields of fuel metering, landing gear, wheel and brake equipment. Having met and mastered service troubles for all types of planes and operating conditions, these service specialists can help immeasurably in building good will for engine builders and air frame manufacturers thru preventive maintenance that will assure lower operating costs.

Any way you look at it, for the best in research, engineering, manufacturing or service in the fields of fuel metering, landing gears and brakes, it pays to insist on a specialist—and the Bendix Products service organization has been a specialist in these fields for over thirty years.

*REG. U. S. PAT. OFF.

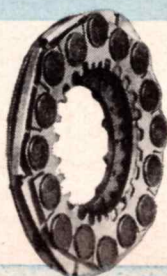
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Division***

Past performance is
the best assurance
of future achievement!



Cerametallic brake lining, developed by Bendix Products engineers, has revolutionized all previous standards of braking efficiency. With this fundamentally different brake lining, braking capacity has been increased 50%, lining life is five times longer and delining and relining are accomplished in half the time.

Here is another outstanding example of Bendix creative engineering ability.



Four slim-waisted Pratt & Whitney Aircraft J-57 turbojet engines in low-slung pods will push Boeing's new 95-ton tanker-transport prototype to cruising speeds of 550 miles an hour and to altitudes in the 40,000-foot range.



ONE OF THE DIVISIONS OF
UNITED AIRCRAFT CORPORATION



America's first jet transport, the 707, rolled out of the Boeing plant at Renton, Washington, on May 13, 1954. The Pratt & Whitney-powered 707 is a prototype for high-speed military tankers or commercial airliners.

New Boeing Tanker-Transport Powered by J-57 Engines

America's first jet transport, the Boeing 707, has been unveiled. In many ways this event is one of the most interesting in modern aviation history.

Here is a completely new transport designed around the most powerful jet engines now in production in the United States. With its four Pratt & Whitney Aircraft J-57s, the new transport has four times as much power as any commercial American airplane now flying. As a military tanker, it will be able to refuel

thirsty jet fighters and bombers at *their* speed and altitude enroute to any distant target. Or it will cruise in the 550 mile-per-hour class carrying 80 to 130 passengers non-stop coast-to-coast or across the Atlantic.

In this great new tanker-transport prototype, as well as in many of the latest Air Force and Navy combat airplanes, Pratt & Whitney Aircraft's J-57 engine is fully justifying the long years and intensive effort required for its development and production.

Pratt & Whitney Aircraft

MAIN OFFICE AND PLANT: EAST HARTFORD, CONNECTICUT • BRANCH PLANTS: NORTH HAVEN, SOUTHLINGTON, MERIDEN
In Canada: Canadian Pratt & Whitney Aircraft Co., Ltd.

TIE- TALKS FEATURE

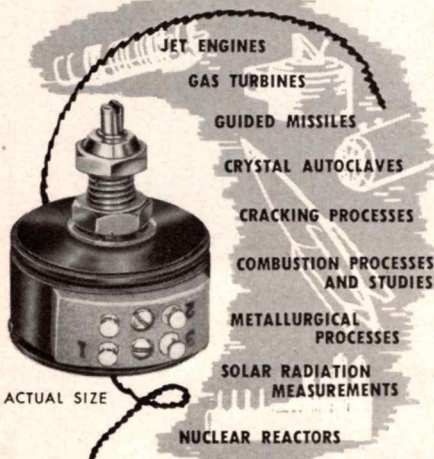
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HIGH TEMPERATURE TRIMMER POTENTIOMETER

... ideal for calibration, balancing, bias adjustment and similar functions in circuitry of Thermocouples, Pyrometers, Bolometers, or Strain Gauges making accurate measurements in high ambient temperature.

Typical operations where the high temperature characteristics of this potentiometer are most useful are in association with instrumentation of:



The ambient temperature range is -55°C to $+145^{\circ}\text{C}$. Stability is assured by pre-aging through temperature cycling. Rugged construction resists deterioration due to shock, vibration, humidity, salt spray, and corrosive atmosphere.

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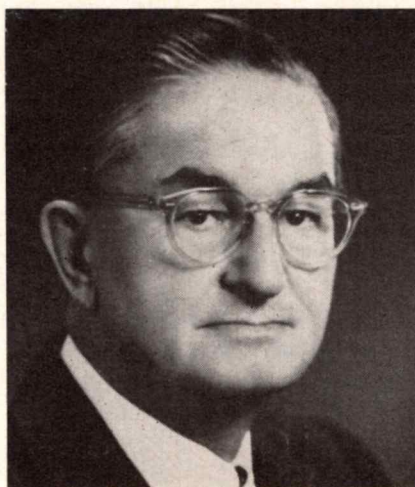
529 Main St., Acton, Mass. COLonial 3-7711

West Coast Eng'g. Facility, 731 No. LaBrea Ave., Hollywood, Calif., WHitney 0108

moted to Manager of Quality Control, Missile Section, Products Division, Bendix Aviation Corporation, Mishawaka, Ind., W. L. Webb, Section Manager, announces. T. S. Torian is the new Manager of Planning, Costing and Scheduling, and Richard F. M. Hamaker has been named Chief Administrative Engineer.

Edward T. Bolton is Executive Vice President and General Manager of Hiller Helicopters, Palo Alto, Calif. . . The second Legion of Merit medal has been awarded Calvin M. Bolster, Coordinator of Development, General Tire and Rubber Company, and former chief of Naval Research. The award was made for Mr. Bolster's outstanding service in the field of guided missile development and anti-submarine warfare. . . Daniel Mapes, Vice President, Walter Kidde and Company, Belleville, N. J., has received an honorary Doctor of Engineering degree from Stevens Institute of Technology.

Purdue University has awarded an honorary Doctor of Engineering degree to Alan Howard, Manager of Engineering for General Electric Company's medium steam turbine, generator and gear department, Lynn, Mass.



Whitley C. Collins, new Northrop president

Whitley C. Collins is the new President and Chief Executive Officer of Northrop Aircraft, Inc., succeeding the late General Oliver P. Echols. Mr. Collins will continue as President of the Radioplane Company, wholly-owned Northrop subsidiary. Robert R.

Miller has been named Assistant to the President.

Joseph F. Chalupa has been appointed Assistant Works Manager, Aviation Gas Turbine Division, Westinghouse Electric Corporation . . . Servomechanisms, Inc., has named John R. Crawford Sales Manager, Components Division, Westbury, N. Y. . . B. W. Clawson has been appointed Manager of the Douglas Aircraft Company's Tucson, Ariz., facility. . . H. S. Tremper has been named Acting Public Relations Manager of Piasecki Helicopter Corporation in addition to his duties as Military Liaison Manager.

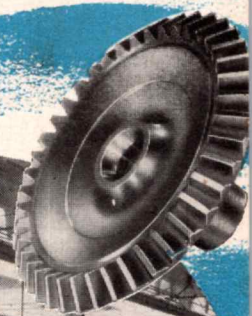
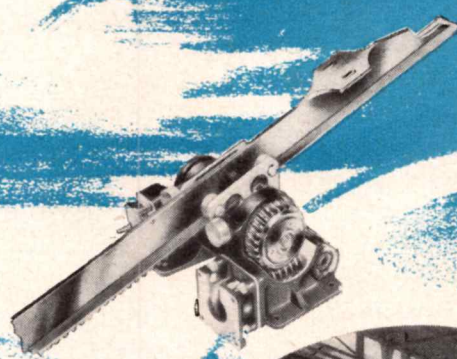
Promotion of six engineers is announced by Republic Aviation Corporation, Farmingdale, N. Y.: Paul S. Baker to Chief, Flight Test, Thermodynamics and Dynamics; Walter R. Bush, to Technical Assistant to the Chief Engineer; James S. Martin to Chief, Structure, Research and Weights; C. E. Pappas to Chief, Aerodynamics and Thermodynamics; Jerry Pavelka to Chief of Aerodynamics, and Robert F. Wichser to Chief Research Engineer.

Norman Caplan has been named Manager, Commercial Engineering, at the Bendix Radio Communications Division, Bendix Aviation Corporation, it is announced by Arthur C. Omberg, Director of Engineering and Research. Mr. Caplan's former post of Chief Engineer, Communications and Navigation Engineering, will be filled by J. H. Taylor.

George W. Bailey, Executive Secretary of the Institute of Radio Engineers and wartime assistant to Dr. Vannevar Bush, has been elected President of the Armed Forces Communications Association. . . Donald C. Burnham has been appointed Vice President-Manufacturing, Westinghouse Electric Corporation, President Gwilym A. Price announces.

Norman L. Winter has been appointed Director, Federal Department, Sperry Gyroscope Corporation, it is announced by George S. Starke, Vice President-Sales. He succeeds Edward F. Lazar, now Assistant to the Vice President and Assistant General Manager.

—FRED HAMLIN



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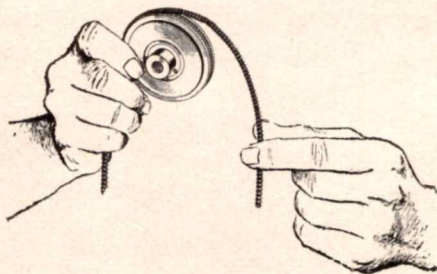
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Teleflex tubular conduit, routed along contours and around obstructions, guides the cable to remote locations, duplicating the motion at both ends of a system.

DESIGN ENGINEERS—For complete engineering data—send to Teleflex Incorporated, 125 S. Main St., N. Wales, Pa., for your copy of Catalog 400E.

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The American people, including hundreds of thousands in the aircraft industry, seem unable to understand the lapse of eight years and three billion dollars between V-J Day and this nation's first combat-ready guided missile. The answer lies in the simple word complexity, one understood all too well by the missile technician but utterly meaningless to the layman. It is the editorial design of this issue to put understandable meaning into missile complexity by taking each of its major problem areas one-by-one and permitting a top expert to explain its broad outlines and promising solutions already in effect or in view. It is our hope that a reading of this issue, and its preservation for future reference, will shed light on some of the facets of the word complexity and give it the frustrating, expensive and all-important meaning it does, in fact, possess in the missile field.

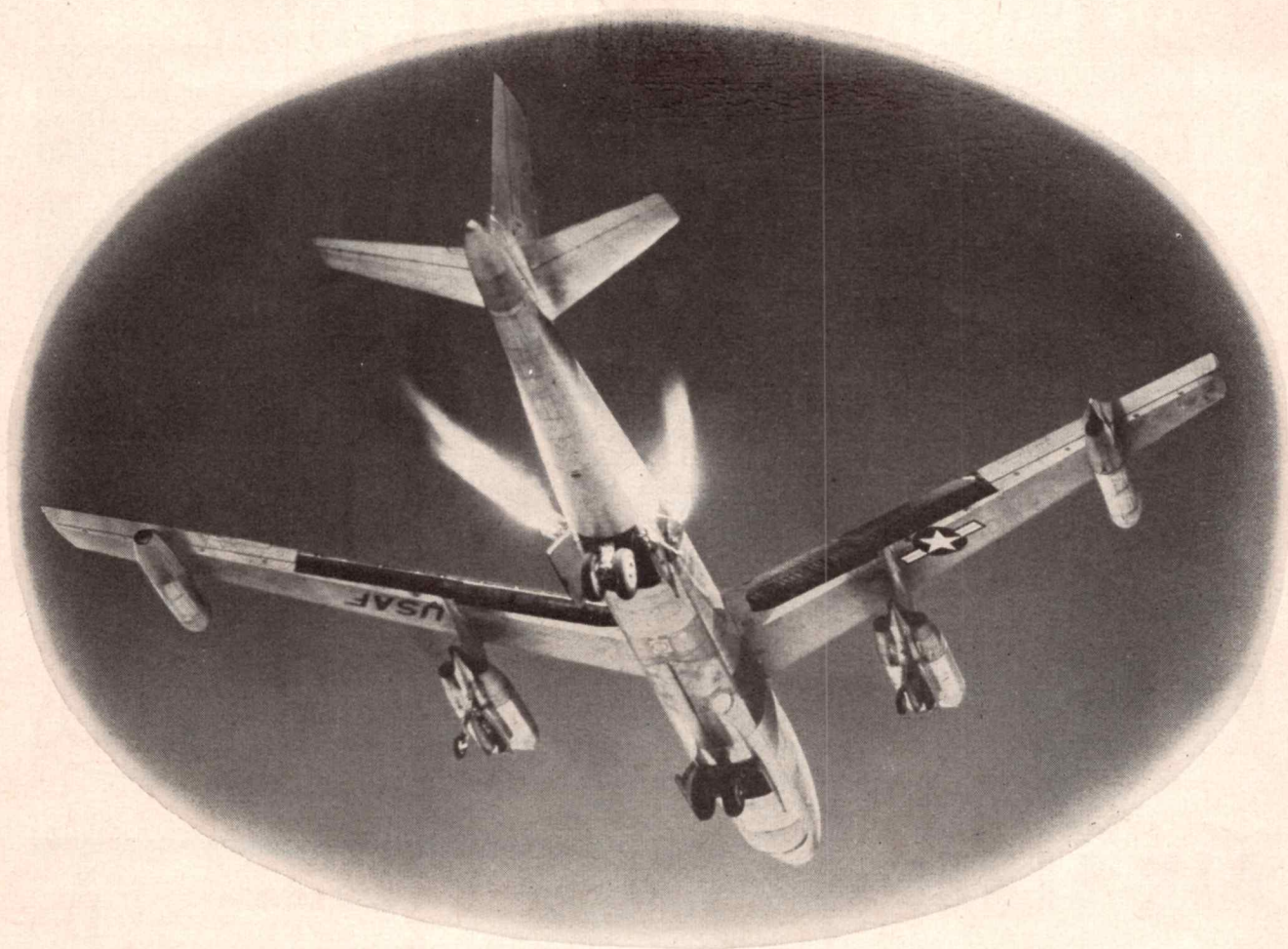
—THE EDITORS

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INCREASED PAYLOAD FOR THE AIR FORCE B-47

This spectacular photograph shows the Boeing B-47B Stratojet shortly after takeoff assisted by Aerojet-General liquid-propellant rocket powerplants.

The new, high-thrust dual rocket installation — which has successfully undergone some of the most severe safety and reliability tests in the history of rocket power — retracts into the fuselage after use,

leaving the aircraft aerodynamically clean.

The outstanding success of this project is the result of the cooperative efforts of the Boeing Airplane Company, Aerojet-General Corporation, and the United States Air Force. As the nation's largest company devoted to rocket power, Aerojet-General is working closely with the Air Force to maintain an unparalleled air superiority.

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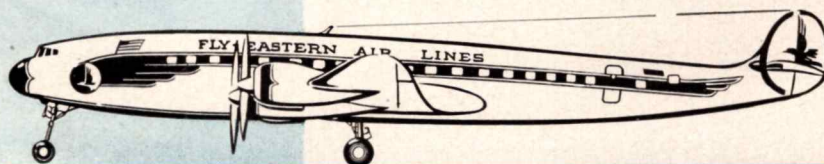
Eastern Air Lines (in common with most of the world's airlines) derives multiple advantages from the use of Vickers Hydraulics. First, it has the best aircraft hydraulic equipment available. Second, it obtains the many benefits of standardization. Third, it has the undivided responsibility of a single source.

Vickers Hydraulic Equipment has proved by hundreds of thousands of hours in the air its claims of longer life, greater dependability, better performance and lower maintenance.

The interchangeability resulting from standardization means a smaller and more flexible inventory of spare parts. It minimizes the number of test and inspection fixtures. It makes for quicker and easier training of maintenance personnel through the need for familiarization with fewer products.

Write for Bulletin A5200-B describing the complete line of Vickers Hydraulic Equipment for Aircraft.

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THE AIRFRAME'S THE SAME —THE POWER'S TURBO-PROP

Here is the Convair YC-131C Military Transport, a conversion to Allison Turbo-Prop power of the Model 340 Convair-Liner. Modified under an Air Force contract, the YC-131C is now flying powered by two Allison YT56 Turbo-Prop engines driving Aeroproducts propellers.

With this installation the Air Force is leading the way in testing the practical operating usefulness of Turbo-Prop engines—paving the way for the change from reciprocating to Turbo-Prop engines in transport and logistic aircraft.

Allison Turbo-Prop design and performance characteristics can help today's transports meet tomorrow's advanced operational requirements of:

- Increased Payloads • Higher Cruising Speeds
- Lower Fuel Cost • Less Maintenance Time and Cost

- Shorter Take-offs and Landings • Greater Passenger Comfort
- Reduced Ground Handling Time
- Reduced Crew Fatigue

Since December 1950, Allison has conducted extensive flight tests with its own Turbo-Liner to exploit the advantages inherent in Turbo-Prop power for transport service. In addition, the Navy is accumulating experience in the Douglas A2D Skyhawk and the Convair R3Y Tradewind—also powered by Allison Turbo-Prop engines driving Aeroproducts propellers.

Today that pioneering is paying off in the availability of Turbo-Prop engines and propellers which will enable military and commercial aircraft to carry bigger payloads, farther, faster and more economically.



Allison

Division of General Motors, Indianapolis, Indiana

Effects of Elements Used in Alloy Steels

This is the second of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

To simplify a rather complex subject, let's outline some of the individual effects of four leading alloying elements used in alloy steels:

NICKEL—One of the fundamental alloying elements, nickel provides such properties as deep hardening, improved toughness at low temperatures, low distortion in quenching certain types of tool steels, good resistance to corrosion when used in conjunction with chromium in stainless grades, and ready response to economical methods of heat-treating.

CHROMIUM—This element is used extensively to increase the corrosion-resistance of steel. It also improves the surface resistance to abrasion and wear. It exerts a toughening effect and increases the hardenability.

MOLYBDENUM—This element exerts a strong effect on the hardenability and toughness of steel. It greatly increases strength at high temperatures as well as the creep-strength of steel.

VANADIUM—An element used to refine the grain and enhance the mechanical properties of steel.

A combination of two or more of the above alloying elements usually imparts some of the characteristic

properties of each. For example, chromium-nickel grades of steel develop good hardening properties with excellent ductility. And chromium-molybdenum steels develop excellent hardenability with satisfactory ductility and a certain amount of heat-resistance. In other words, the total effect of a combination of alloying elements is usually greater than the sum of their individual effects. This interrelation must be taken into account whenever a change in a specified analysis is evaluated.

Bethlehem metallurgists can be of considerable help to you in selecting the proper alloy steel for any use. These men will gladly give unbiased advice on alloy steel analysis, heat-treatment, machinability, and expected results. Feel free to call upon them at any time.

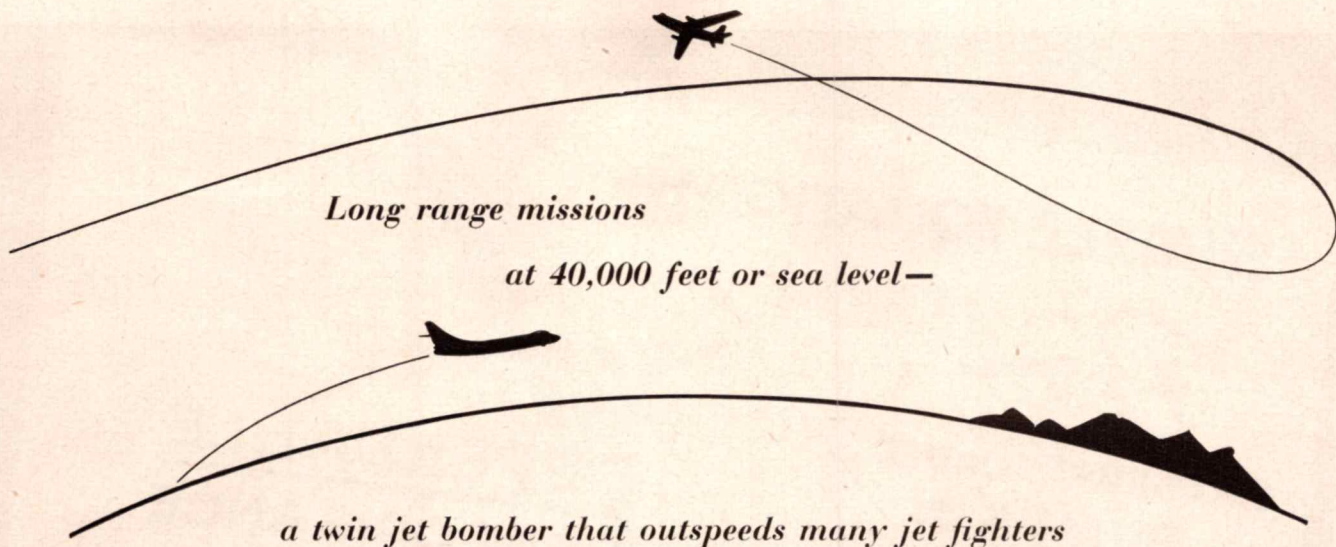
And please remember, too, that Bethlehem manufactures all AISI standard alloy steels, as well as special-analysis steels and the full range of carbon grades. You can rely upon their quality, always.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM *ALLOY* STEELS





—the U. S. Navy's Douglas A3D

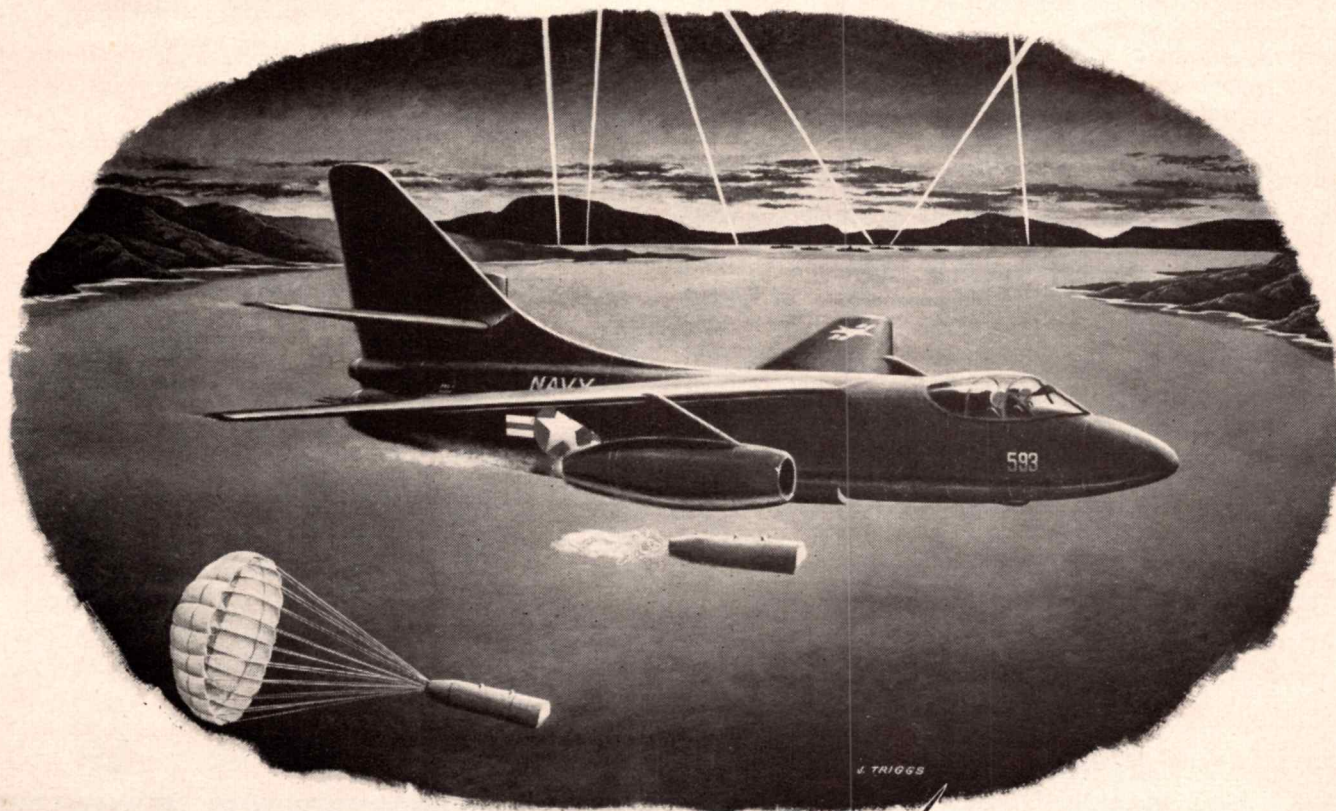
Compact in design, outstanding for its work-weight ratio, the carrier-based twin jet A3D typifies a Douglas-led trend toward less complex combat aircraft.

Simplification, which gives A3D greater speed, range, and payload

than any comparable bomber, also results in great versatility. The Douglas A3D can fly high-altitude attack missions or serve as a mine layer. Largest of all carrier-based aircraft, it can handle—in its internal bomb bay—the bulkiest bombs, torpedoes,

or other naval munitions designated for carrier action.

Design of A3D is another example of Douglas leadership in aviation. Developing planes that can fly *faster and farther with a bigger payload* is a basic Douglas concept.



Be a Naval flier—write to Nav Cad, Washington 25, D. C.

Depend on **DOUGLAS**

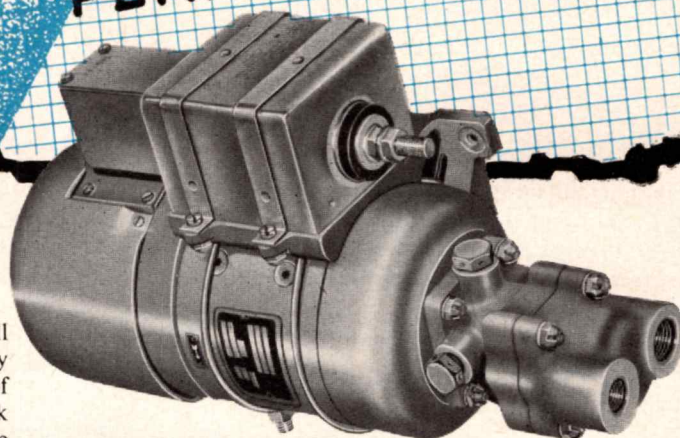


First in Aviation

SIMPLE EQUATION:

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PRESSURE-LOADED
PUMPS =

**DEPENDABLE
PERFORMANCE**



Pesco Model No. 111530 Electric Motor-Driven Hydraulic Pump with 0.056 cubic inch displacement, 1.3 gpm @ 3000 psig, 26 Volts. Weight 28 lbs.

Engineers responsible for the design and operation of all types of aircraft never compromise on dependability. By this same logic, they rely on the experience and ability of Pesco for fuel and hydraulic pumps that will insure peak performance. They know from long experience that the dependability of Pesco products results from several factors—all of them important to aircraft design and operation.

First there is Pesco experience. Since 1933 Pesco has concentrated its full facilities on the continuous development of aircraft pumps, motors, and accessory equipment. The successful solution of thousands of pumping problems has provided Pesco with unmatched "know-how" in pump design, characteristics, and application.

Then there are Pesco engineering and research—continuous and complete services using advanced technology in both design and materials to provide improved products and solutions to pumping problems.

And finally there are Pesco production facilities—geared to produce precision units in volume. High-precision machines and advanced production and testing techniques are reflected in the consistently high quality of all Pesco products.

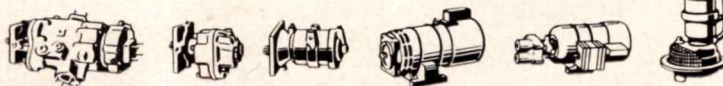
These same Pesco advantages can be used to solve your specific pumping problems successfully. Simply call or write the Home Office, Bedford, Ohio.

YOU CAN RELY ON **PESCO** *Pressure Loaded* **PUMPS** FOR THESE ADVANTAGES

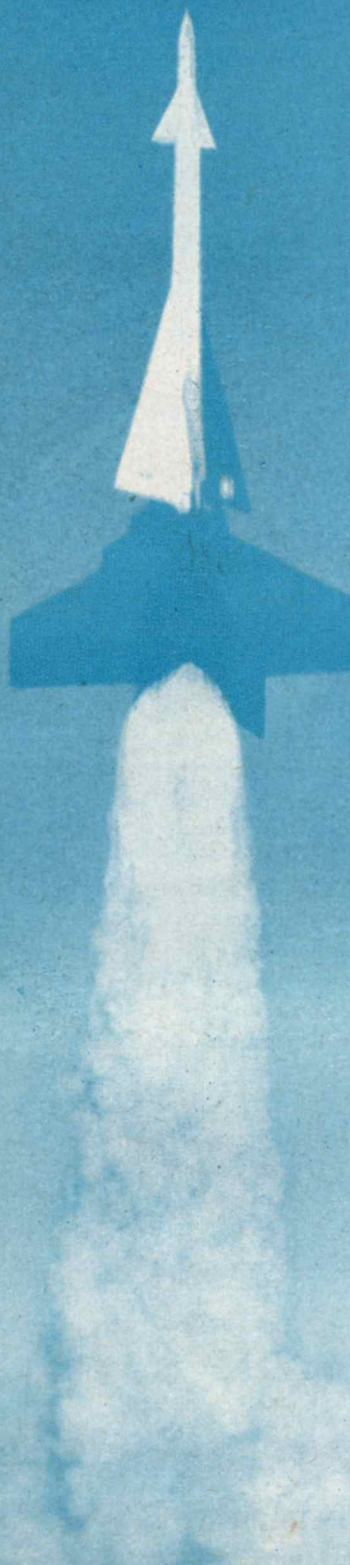
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AIR PUMPS	• POWER PACKAGES
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**AERO
DIGEST**

Aero first

A pioneer in the field of guided missiles, AERO DIGEST brings to its engineering readership with this special all-missile science issue the first full-panel report of its kind in the history of aeronautical journals. Security has made it most difficult to edit and publish this special issue without either violating the law or compromising patriotism.

Despite stringent security on the subject, the great sweep of this nation's mighty effort in the missile field has passed into public knowledge at least the broad outlines of our progress and, in a multitude of cases, permitted revelation of photographs, drawings and data on specific missiles.

It is from these significant glimpses beneath the security curtain that this special issue is drawn. We think it displays a record of powerful accomplishment, including news of the nation's first on-duty pilotless bomber (now in service in Germany) and its first on-duty production guided air-to-air-missile.

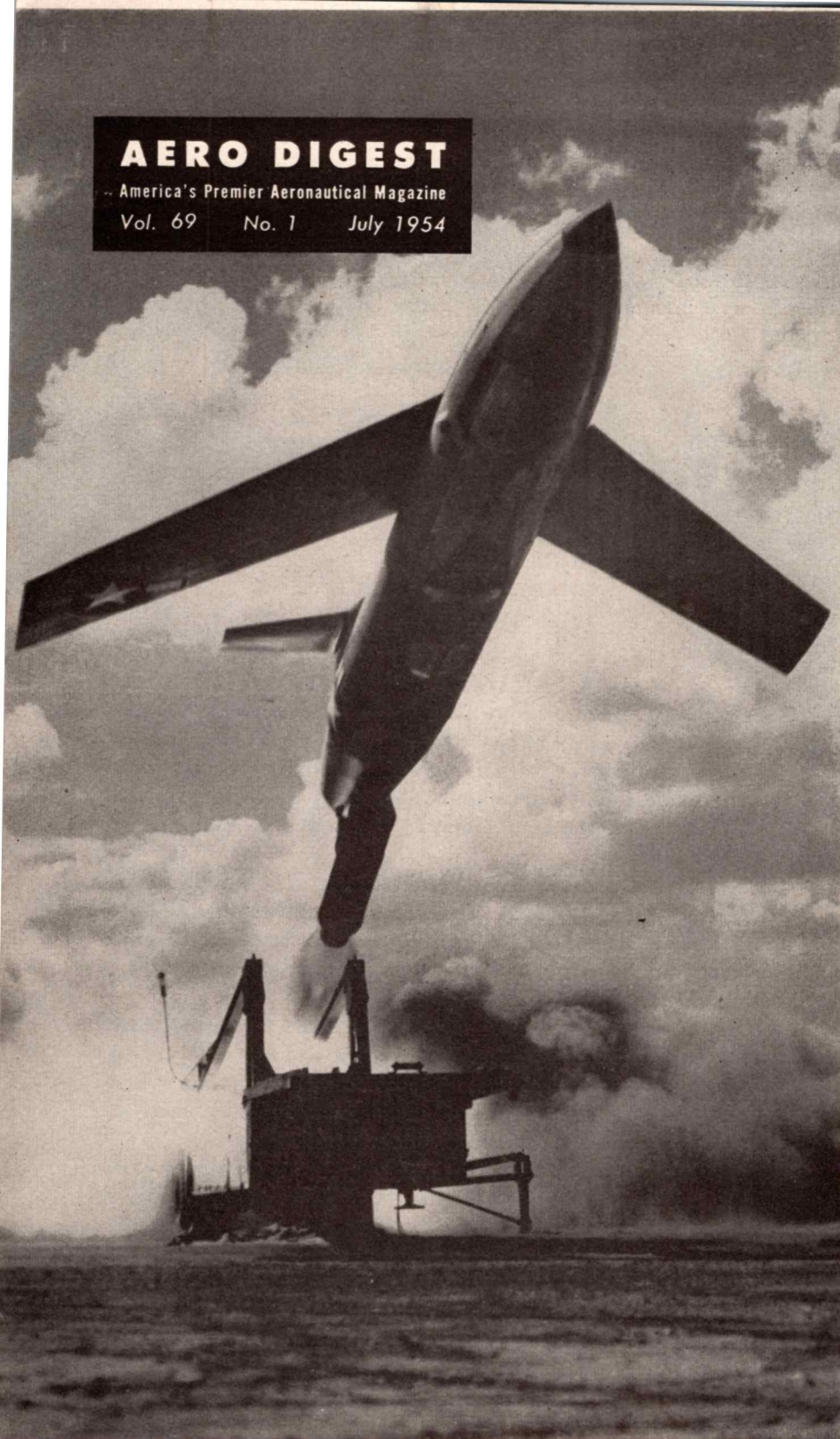
These are now permanent weapons in our arsenal of Air Power. More important, they give inherent indices to the remarkable progress going on behind the security curtain. The scientific and technical features in this issue outline and explain this progress and point unmistakably toward the shape of things to come.

ROBERT McLARREN
Editor

AERO DIGEST

America's Premier Aeronautical Magazine

Vol. 69 No. 1 July 1954



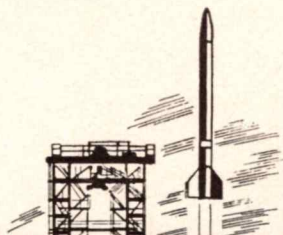
IT has often been asked why the guidance problem has been such an Achilles' heel in the guided missile program, the critical factor limiting the pace of development of these weapons.

The problem is very often passed off as a necessary annoyance, especially by those whose experience has been mostly with airplane design. They are apt to point out that since guidance systems usually contain vacuum tubes, which are reputedly not too reliable—how can we expect much better in our results? This is a misinformed, over-simplified diagnosis of a most important problem—for not only can no convincing brief be made for tube reliability, but there are many other major facets to the perplexing challenge of guiding a missile accurately to its target. Even if the tube or its transistor counterpart were 100 percent reliable, a host of formidable problems would still remain. These deserve a more enlightened understanding. Let's consider a few of them.

The guidance engineer of Air Force's Martin B-61 *Matador* pilotless bomber, for example, faced a problem similar to that of a golfer who has to drive his ball on a par-three hole—and make a hole-in-one, on the fly, without bounce or roll. And he has to do it day or night. Moreover, he must demonstrate that he can do it with five out of every ten balls he drives.

All the golfer would have to do—as the guidance engineer might explain it—is to aim and launch a very simple, practically homogenous spheroid. He would be called upon to transfix a familiar

Martin B-61 Matador is launched



missile science

STATEMENT OF THE PROBLEM

By WELCOME W. BENDER

Manager of Electronics, The Glenn L. Martin Co.

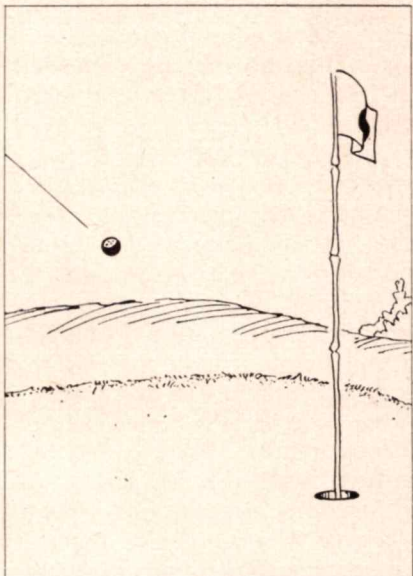
target with it using well-known techniques practiced for years by golfers. Yet no golfer can even come close, despite the best of human training, experience, judgment and control. Regardless of the effort expended, he simply cannot do it.

The guidance system designer must face just such a problem—and find a way to solve it. Surprisingly enough, it can be done, even if it often takes a bit longer to achieve than it does to design the airframe itself. Let's look a little closer.

For the golfer in our analogy, there are few choices. Primarily, he must aim and strike the ball with precisely the right impact, in precisely the right direction, allowing for wind, spin and whatever else might affect the ball's flight. Even were he allowed elaborate computers and aiming devices, it is doubtful that he could ever predict all the inflight variations which might modify the final result. And in this game, a one-putt shot to the green isn't good enough. For practical purposes, a guided missile that only *almost* completes its mission is useless.

Now, if our golfer is allowed a little imaginative leeway perhaps he may suggest at least two highly elaborate ways of making that hole-in-one more frequently. He might, for instance, conceive of an apparatus which would hit the ball as accurately as possible, then watch its flight, measure its course with utmost precision—and compute corrections to it. If, somehow, he could get these corrections to the ball in flight, he might make the grade. Again, through some mechanistic sorcery, he might impart sufficient "intelligence" to the golf ball, whereby it would be able to measure its own progress during flight—to predict its future course and correct itself to the right or left, up or down, in such manner as to drop accurately into that 4-in. diameter cup on the putting green.

This analogy may appear fantastic. Yet in its precise requirements, it is quite comparable to the typical missile guidance problem. In fact, a missile like the



All the golfer has to do is to drive the ball so as to transfix a four-inch cup! several hundred yards away for a hole-in-one "on the fly, without bounce or roll!"

Matador may be guided to its target by any of the three general methods suggested—as well as by others, all of comparable difficulty.

The missile problem is complicated by the fact that human intelligence and judgment founded on mature experience must be successfully supplanted by electronic and electro-mechanical devices to measure, compute, predict, correct and communicate with the missile. Most of these devices have to be carried by the missile in flight. This implies that whatever apparatus is employed must be thoroughly adjusted beforehand—for the tactical missile, unlike the conventional airplane, is flown only once. To our analogous golfer, this denies even a practice shot!

The guidance of a missile is further complicated by many other factors besides the very difficult one of reducing the functions suggested by the golfer to the terms of a non-human mechanism. For example, it is possible, for any given set of practical con-

ditions, to design devices which perform the logical steps that the human mind performs in carrying out an instruction of the complexity we are envisioning in connection with missile guidance. But it is quite impractical to design "judgment" apparatus to take care of the myriad of contingencies brought about by random variations of the conditions of the problem.

It would be an extremely complicated exercise to design the missile capable of making a choice of decisions in the event that any one of its components fails to provide its expected performance. If our hypothetical golfer had an aching finger, he might favor it to some degree without upsetting all the other factors. The marvelous resourcefulness of the man — his adaptability in such situations — is most difficult if not impracticable to reproduce in inanimate mechanisms, all the promise of electronics and its allied sciences notwithstanding.

This last point, which may ap-

TABLE I		
No. of elements in chain	Probability of success of each element	Composite probability of success of mission
10	.900	.35
100	.950	.006
100	.990	.37
100	.999	.92

pear trivial, is the key to a resulting and much more serious problem. As has been pointed out, it is well-nigh impossible to design into one machine, to be used for one flight, anywhere near the resourcefulness that a human possesses by reason of all his past experience—that is, the ability to make an on-the-spot choice of substitutes in the event of lack of performance of any component. Consequently, the guided missile is quite helpless upon the failure of any one component or element.

This is especially true of the guidance system. Why, it may be inquired, need this be true? A multi-engined airplane is designed to fly even if one engine fails. Perhaps so, though few can complete the original flight plan with only three of four engines. Nevertheless, the point is well taken. But the comparison is not quite that simple.

In a multi-engined airplane, all four engines share the thrust load, and none represents any excess when all are operating. Second landing gear are never carried as stand-bys in the event of failure of the primary gear—although certain components, such as pumps, may be duplicated for emergency operation.

It is quite a different matter to build duplicate devices to perform the guidance function—sharing, as it were, the measuring, correcting, controlling and aiming functions. This is tantamount to asking two golfers to share the task of aiming a single club! One golfer, in this situation, is clearly superfluous. Even if the control were left to one guidance system, with a second complete system carried in the missile to take over should the first fail—how could the decision be made as to what the conditions constituting failure of the first system? What is to make this choice—still a third, even more complex system? It is obvious that this line of reasoning leads quickly to exorbitant complications, and the weight of “contingency” equipment, let alone the complication and expense rules it out in most missile designs.

The present state of the art, therefore, with a few notable exceptions, generally results in the

design of a chain of elements comprising a single guidance system predicated on the premise that all parts are designed to work without “crutches”—and that failure of any link in the chain constitutes failure of the weapon mission. Essentially, nothing is carried which is not required to perform during the mission.

Curiously enough, however, in line with this philosophy, no fuses are used to protect any part in the event of failure of any other part. Is it any wonder that, to compensate for this condition, parts for guided missiles must meet reliability standards far in excess of those required for manned aircraft? Though often overlooked, this is the case in any successful missile program.

The reliability required of components of a guidance and control system of a missile can readily be appreciated in the light of a few simple calculations — calculations that are familiar to the statistician but not always recognized by the designer.

For example, consider the guidance system of the *Matador* to contain many elements acting in series. There are a fuel system, an engine, a generator, regulated power supplies, antennae, receivers, amplifiers, gyros, computing elements, hydraulic servos, measuring potentiometers — to mention but a few. Each of these depends on dozens of sub-components, such as resistors, con-

densers, transformers, synchros and diodes.

Now let us assume that there are only 100 links in the chain, all of which must perform to complete the mission. In reality there are many times this number. The probability that the whole system will operate correctly is determined by the product of the individual probabilities of successful operation of each of the 100 elements. This is to say that if each element has a 95 percent chance of operating through the entire flight, the mission probability is .95 raised to the one hundredth power. This can be shown to be equal to 0.6 of 1 percent chance that the mission will prove successful. This is not good enough!

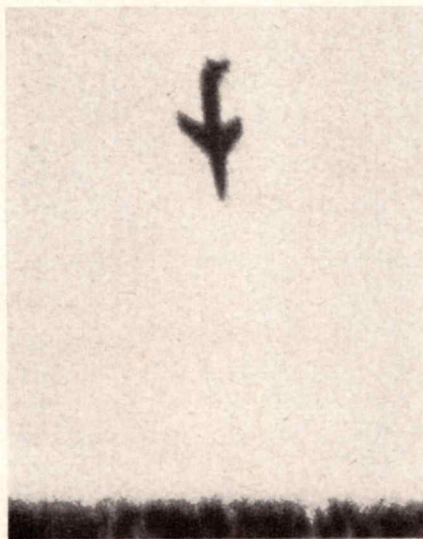
If the probability of success of each element is increased to 99 percent by improving the quality of each of the components, the probability of the whole missile completing its mission is still only 37 percent! Each of the 100 component elements, in this example, must have less than one chance in a thousand of failing, if the missile is to have better than a 90 percent probability of success. Similar numbers can be readily computed for other examples.

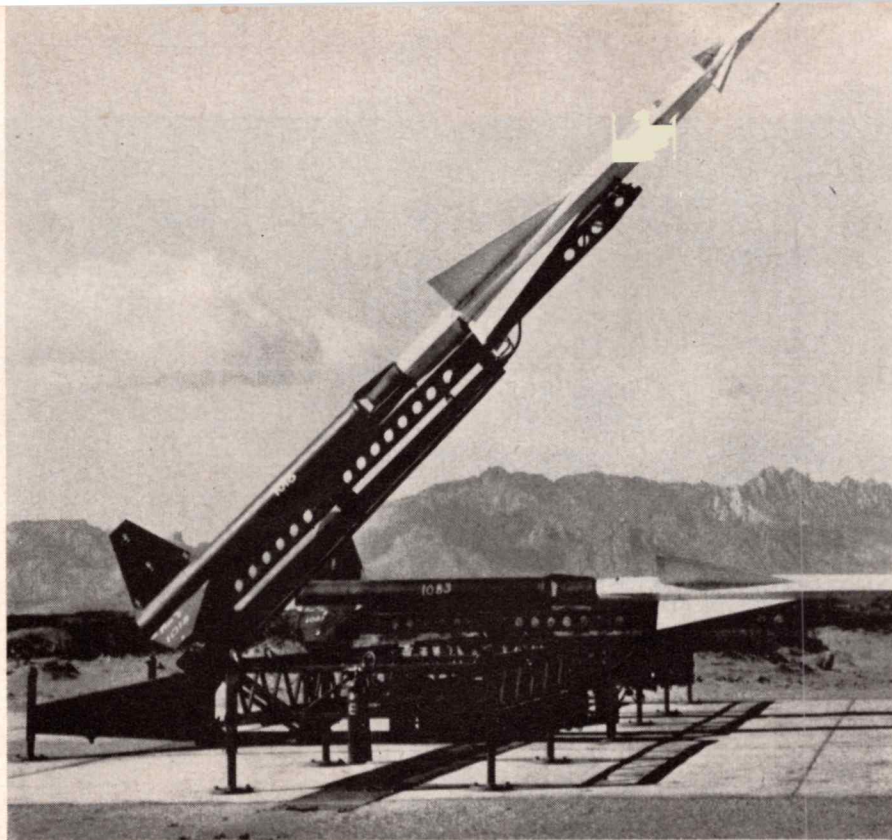
They clearly indicate the extreme care necessary in the design and quality control of the many hundred—indeed, thousands—of parts that go to make up an apparatus qualified to replace a human flight crew. Table I shows a number of typical probabilities.

It has been attempted here to outline a few of the many factors that combine to make the problem of missile guidance and control a measure or so more difficult to solve than the design of the airframe itself. We have considered only a ground-to-ground type missile. The problem of an air-to-air missile is even more difficult in its requirements. Without the marvels of recent electronic advances, no real start could have been made on the problem. Moreover, even by taking advantage of all of them, the problems are by no means solved.

Yet none will say that the goal cannot be attained, even though we doubt that we'll ever see a golfer who can guarantee a hole-in-one every other shot! END

Terminal dive of *Matador* after a guided flight of several hundred miles





Missile is elevated mechanically and automatically to electronically-determined firing angle

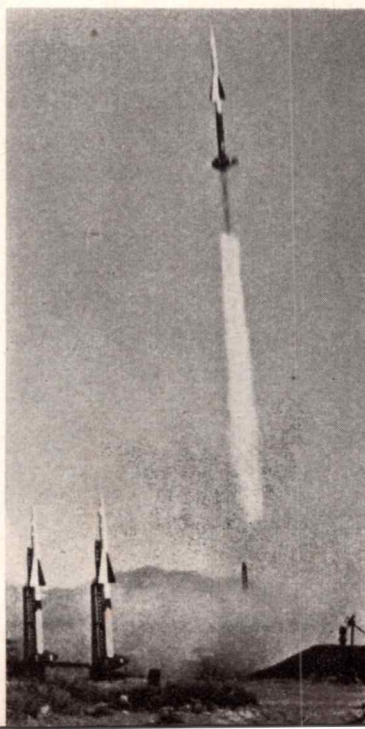
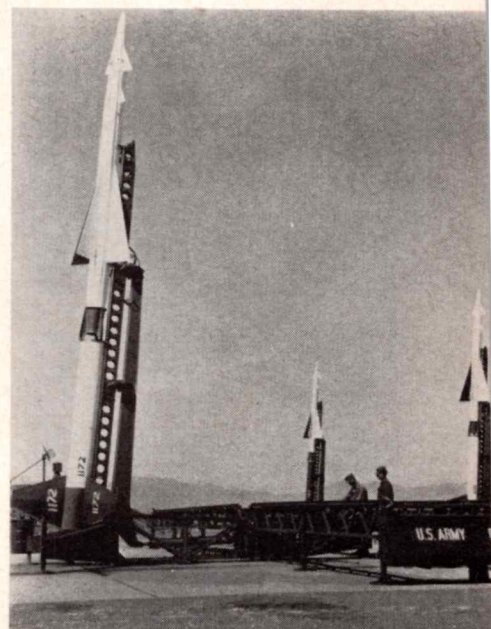
In near-vertical firing elevation, battery of missiles is ready for automatic firing by radar signal

NIKE

America — at last — has a proven, production missile on its air-defense firing line

FIRST combat-ready supersonic antiaircraft missile to be deployed for air defense of the United States is NIKE, named for the "Winged Victory" of Greek mythology. The awesome weapon was developed in eight years by a service-industry team composed of engineers from the Army Ordnance Corps, Western Electric Co., Bell Telephone Laboratories and Douglas Aircraft Co.

NIKE is a weapons system consisting of the airborne missile, and an array of electronic ground equipment which picks up the target, automatically fires the missile and controls its flight to target interception. Most current mass pro-



Nike streaks skyward under impulse of booster rocket ignited by automatic signal

Bell Telephone Laboratories technicians study plot of simulated Nike mission recorded on plotter



Technician makes adjustment to panel of complex Nike mission simulator developed for missile design

duction of the control equipment is by Western Electric while rockets and components of the associated ground-handling equipment are produced by Douglas.

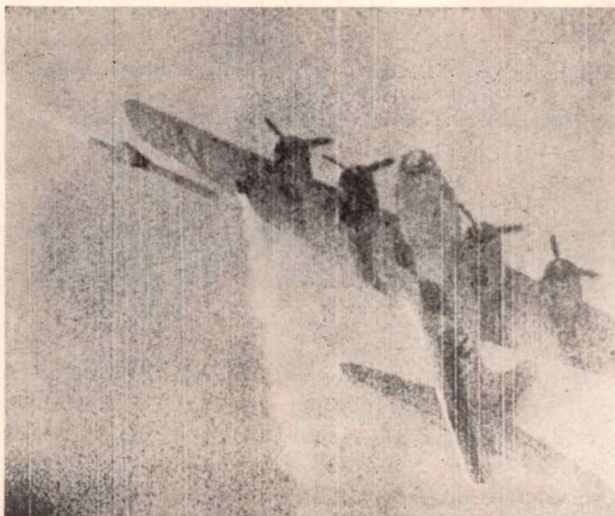
The missile itself is a two-stage rocket with sharply-swept cruciform fins near the nose and similar, larger fins near the stern. It is about 20 ft. long and one foot in diameter. Liquid propellants are used for fuel. A booster section, with triangular fins, is used for initial acceleration of the missile to supersonic speed. The spent booster is then automatically separated and NIKE continues on its guided flight.

An explosive warhead and electronic guidance equipment are carried in the body of the missile. The ground detection equipment picks up the blip of approaching aircraft and, after automatic identification procedures establish them as hostile, sets in motion automatic tracking and firing circuits. When the enemy aircraft pass an invisible electronic line in the sky, NIKE is fired automatically.

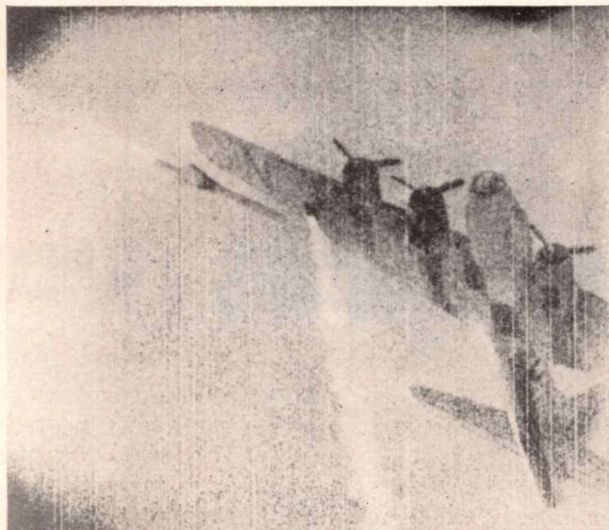
NIKE batteries are now being installed in the vicinity of Washington, D. C., New York City, Detroit, Seattle, Los Angeles and other strategic centers. END

View of complete Nike simulator at Bell Telephone Laboratories shows gyro unit under glass cover

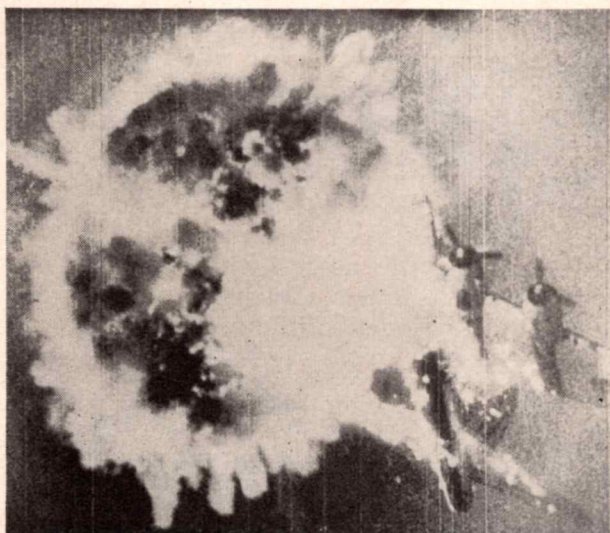




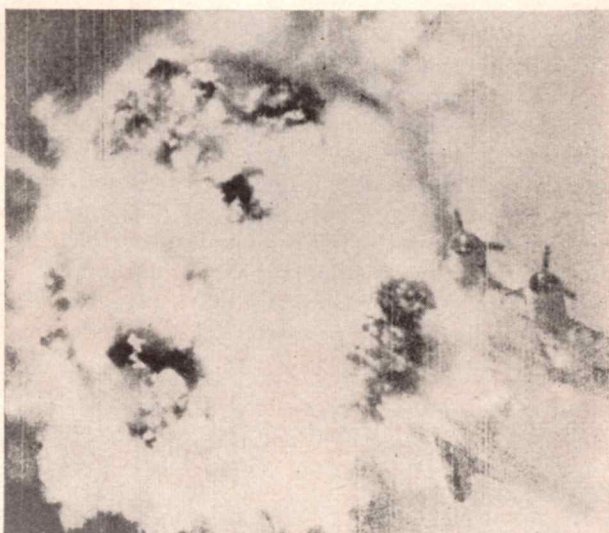
Pilotless Boeing B-17 target as Nike missile (upper left) nears. Smoke tank aids ground photographer



Nike (under wing at left) instant before contact is guided by target-seeking head into B-17

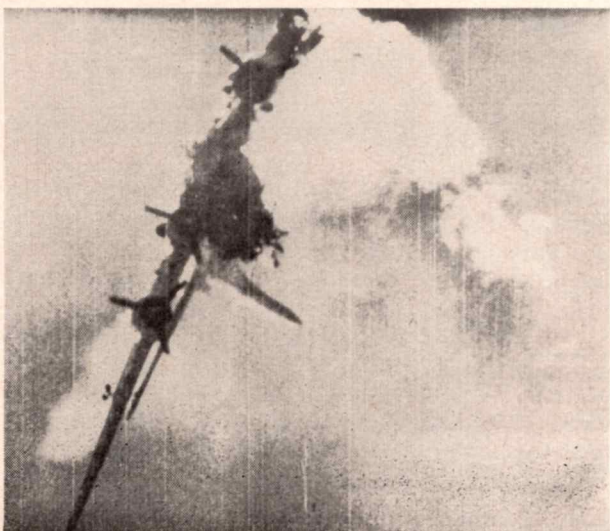


Nike hits B-17 in wing at starboard outer nacelle and detonates warhead

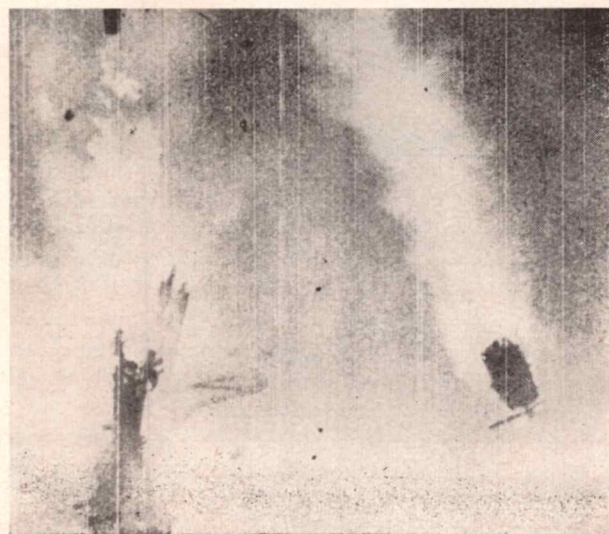


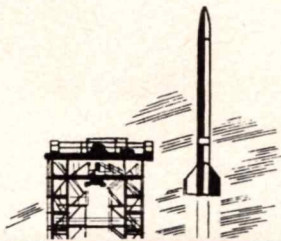
Enveloped in explosion, drone B-17 simulates enemy bomber at 40,000 ft. level

Outer wing blown off, B-17 goes into roll with wing tanks ablaze



Force of roll creates structural disintegration and another victory for Nike





missile history

AMERICA'S FIRST PILOTLESS AIRCRAFT

Nearly four decades of secrecy are smashed by this first revelation of details of the "Bug"

THE origin and history of the guided missile in the United States have been rightfully shrouded in military security since its infancy. The full story of the earliest developments can now be published for the first time.

It should be pointed out that the term "guided missile" is used here to associate the subject with the appropriate field of science. Actually the earliest missiles were referred to as "aerial torpedoes" and were pre-set flying bombs of the same order as the German V-1 of World War II. Regardless, the aerial torpedo and the guided missile have much in common; both are pilotless missiles launched against predetermined targets. But the torpedo makes a controlled

at the Sperry plant. The development progressed rapidly throughout the summer and Hewitt brought the device to the attention of the Navy Department in September after noticeable successes in tests and expenditures of considerable funds by Sperry.

Lieutenant T. S. Wilkinson of the Navy Bureau of Ordnance, on the 12th of September, 1916, witnessed tests of a hydroplane fitted with gyro stabilization, course keeping, and distance gear. Wilkinson was a passenger in the plane piloted by Lawrence Sperry.

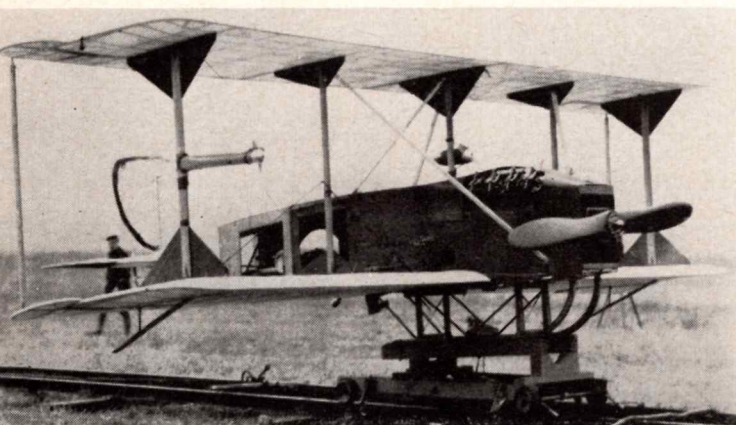
After takeoff, Sperry turned the controls over to the automatic equipment, which caused the plane to climb to a predetermined altitude, maintain the plane at

the sponsorship of the Bureau of Ordnance. A sum of \$200,000 was set up and Commander B. B. McCormick became the naval director of the project.

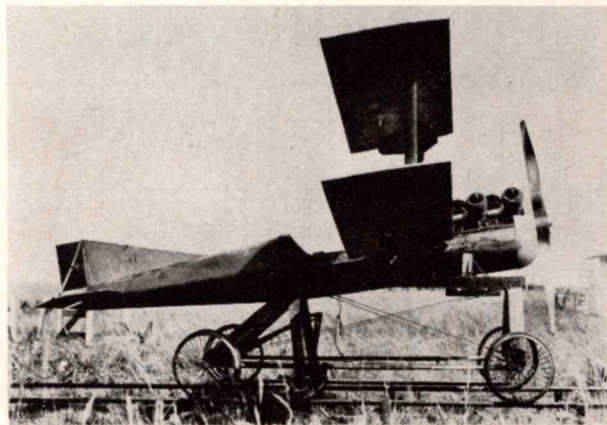
The first tests were performed in naval seaplanes of the N9 type and many automatic flights were made under supervision of a human pilot during the fall of 1917. The equipment functioned so well that it was decided the Navy should develop a plane of special design for F. B. applications and the Army should be invited to examine the project.

General George O. Squier, Chief Signal Officer of the Army, Rear Admiral Earle of BuOrd and others witnessed a successful automatic flight demonstration of the

Curtiss-Sperry Flying Bomb of 1917-18 weighed only 500 lb. but carried 1000-lb. explosive load



Kettering Aerial Torpedo at Carlstrom Field, Arcadia, Fla. Sept.-Oct., 1919



flight while the missile is guided throughout its flight.

Peter Cooper Hewitt, eminent scientist and a member of the Naval Consulting Board, advanced the first practicable suggestion for building and developing a self-controlled flying bomb in April, 1916. He personally furnished the initial funds and arranged with Elmer A. Sperry, also a member of the Board, for preliminary work

that altitude, keep the plane on a set compass heading and cause it to dive at the end of a preset time of flight. Wilkinson was greatly impressed with the excellent performance and so reported the facts to his chief, Rear Admiral Ralph Earle.

The Secretary of the Navy Josephus Daniels, on May 22, 1917, approved the Sperry-Hewitt Flying Bomb (F.B.) project under

N9 at Amityville, L. I., on Nov. 21, 1917. Shortly thereafter the Army began work on the aerial torpedo development with Charles F. Kettering as the industrial leader of the project and Colonel Bion J. Arnold, a member of the Naval Consulting Board, as the military leader.

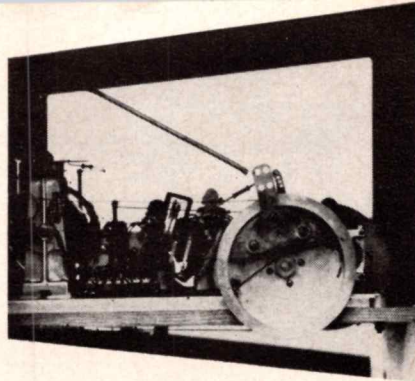
Conversations between Glenn H. Curtiss and Elmer A. Sperry on the subject of a special F. B. de-

By REAR ADM. DELMAR S. FAHRNEY, USN (RET.)

and ROBERT STROBELL

Deputy Curator, National Air Museum

Sperry automatic pilot installed in
Curtiss-Sperry Flying Bomb 1917-18



sign culminated in the issuance of a two-page specification which was approved by the Navy. The plane must be designed and built in 30 days. It was required to carry 1,000 lb. of explosive, have a top speed of 90 mph, fuel for 50-mi. range, weight empty of 500 lbs., provision for catapult launching and, finally, "the engine should be as light as compatible with its duties."

The plane was delivered in 30 days, as specified, to the Sperry test field at Copiague, L. I. This was the first plane designed for missile use to be delivered in this country.

The most urgent problem facing the F. B. pioneers was that of launching the F. B. successfully. Many devices were tried before the final solution was found, a flywheel type of catapult designed by Carl L. Norden, of bombsight fame.

In the meantime Ensign Lawrence Sperry began testing the Curtiss-Sperry F. B. on ice runners. On Feb. 7, 1918, he struck a bank of slushy snow. His plane did two complete somersaults and was wrecked. Young Sperry came out of the crash unharmed.

On March 6, 1918, the Curtiss-Sperry F. B. was launched successfully and performed all the functions planned for the test. The machine climbed steadily flying in a straight line. When the distance gear cut the throttle

at 1,000 yd., as was set, the plane made a slow right spiral into the water.

The F. B. test of March 6, 1918, marks the first entirely successful flight of an automatic missile in this country if not in the world. The fact that an unmanned plane was under the control of automatic equipment from the catapult launch, through a smooth stabilized flight until the automatic distance gear ordered it to descend to the water is unique in aviation history and up to that day had no parallel in world achievement.

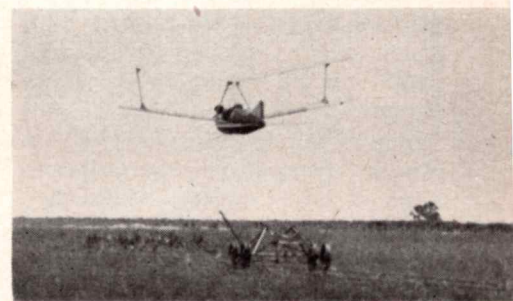
Another memorable flight was made by an N9 F. B. on Oct. 17, 1918, when it was launched from the flywheel type catapult. In the words of Commander McCormick, "it climbed steadily and flew in a perfectly straight line. The distance gear failed to function and in consequence the plane continued on its course and would not finish its run until the gasoline was exhausted—nothing has been heard of the plane from the time that it disappeared from view on the field at Copiague."

Turning back to 1917, we find General Squier actively interested in an aerial torpedo for Army use. He established a committee to investigate the matter. They returned an unfavorable report but Charles F. Kettering, a member of the committee, submitted a minority report expressing his belief in the "automatic airplane," pointing out that such an aircraft should be adaptable to mass production and constructed of inexpensive materials. He was authorized to undertake the development.

On Dec. 24, 1917, he called a meeting in Dayton and outlined his concepts of an aerial torpedo to Mr. Harold E. Talbott, President, Dayton Metal Products Co., Mr. W. A. Chryst, Dayton En-

gineering Laboratories (Delco), along with mechanical engineers, chemists, and research personnel of these companies. The development work was divided into three portions: airplane design, engine, and controls.

General Squier specifically asked that Orville Wright be consulted on all aerodynamic work, and the airplane design was turned over to the Dayton Wright Airplane Co. Under the urgencies of war these companies began work immediately. The skillful manner



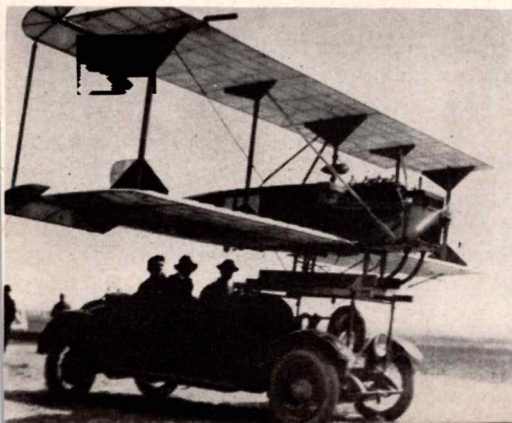
Kettering Aerial Torpedo takes off
on 19 1/2-mi. flight Oct. 28, 1919

in which the unprecedented problems were solved is somewhat astounding. Within ten months the aerial torpedo was ready for flight test.

The final design which emerged in the fall of 1918 was a small biplane with 15-ft. span and no provisions for a pilot. While it had conventional lines, all similarity ceased at this point. It was developed as a pure flying bomb, expendable, and constructed of the most inexpensive, abundant, and noncritical materials.

The Bureau of Standards developed and produced 1,000 yd. of exceedingly strong paper made of jute and manila rope which was used to cover the wings, fin, rudder, elevator, and horizontal stabilizer to replace linen or fine cotton fabrics needed for fighters and training airplanes. Low-grade wood was used in the spars, half

Marmon car chassis used to test
Curtiss-Sperry Flying Bomb May, 1918



ribs, formers, longerons, and I struts. Heavy prefabricated pasteboard formed the conical aft section of the fuselage and the leading edges of the wings.

By chance, Mr. Harold Wills became interested in the engine development which was turned over to him at the De Palma Mfg. Co. Numerous engines were considered but the final choice was a 38-hp, two-cycle, four-cylinder, 90° V weighing about 120 lb. which had many advantages besides being inexpensive to produce. It was designed to operate at maximum power during its short, one-way flight. Orville Wright contributed to the propeller design based on the same specification.

Mr. Kettering personally developed the remarkable control system. The rudder and elevators were actuated by a pneumatic control system supplied with vacuum or pressure from the crankcase of the two-cycle engine. This pneumatic system was adapted from an Aeolian Player Piano which Mr. Kettering owned and admired because the bellows produced complicated movements. The Aeolian Player Piano Co., New York City, undertook the development and produced the pneumatic controls.

Bellows were actuated by air bled from ports on a gyroscope to produce horizontal flight and directional control. Kettering was reluctant to use the gyroscope because it was expensive and contained precision ball bearings impossible to obtain in quantity. Elmer Sperry gave Kettering a gyroscope and assisted in its application to the aerial torpedo. Kettering showed great ingenuity in eliminating the expensive bearings and adapting the gyroscope to the pneumatic controls. His work was cited by General Squier as an "achievement of the first magnitude."

Altitude control was achieved by utilizing an aneroid which cut in on the elevator control to maintain nearly level flight. A standard National Cash Register customer counter, actuated by an "air-log" impeller, measured the air distance or range and cut the ignition over the target area.

The aerial torpedo was further simplified by eliminating ailerons and the necessary controls. Orville Wright recommended a dihedral of 10° to produce inherent stability and this feature was incorporated successfully. No landing gear was necessary. It was launched by its own power from a four-wheel carriage running on small pipe rails. Auxiliary electrical equipment supplied electricity for starting the engine and gyroscope.

Produced in quantity, the cost per unit was an estimated \$575.00 complete. Payload included 200 lb. of explosive and 30 lb. of low grade commercial gasoline for a flight of 50 mi. Variations in load could extend the distance to 100 mi.

Designed with field use in mind, it could be assembled in 4½ min. with a screw driver and socket wrench.

The first launching took place at South Field, Dayton, Ohio, Oct. 2, 1918, following ground tests. The official report states that the aerial torpedo reached a speed of 42 mph, sailed upwards, turned to the right, then to the left, back to the right; still climbing, it whiplashed and crashed. Perhaps this flight inspired someone to call it "the bug," which became its popular nickname in official records.

The flight was erratic and obviously over-controlled. But it proved that the aerial torpedo could be successfully launched and that it was reasonably stable in flight.

On Oct. 4, an aerial torpedo,

after spectacular aerobatics, left the aviation field completely out of control and proceeded in large circles to drift with the wind while it climbed to an estimated 10,000 ft. About an hour later, it was found 20 mi. from the field. Country people observed the flight in disbelief, unaware that it contained no drunken or sleeping pilot. It disintegrated during its plunge to the ground, scattering parts over a wide area.

Complete success was achieved on Oct. 22, when an aerial torpedo climbed to a predetermined altitude, leveled off, proceeded on a direct course and dove to the target area at 500 yd., all components functioning properly. It was a gratifying test for the pioneering group.

At this point it was decided to move the tests to an uninhabited area to avoid publicity and maintain secrecy. Twenty-five complete bugs were originally ordered and an accelerated effort was made to complete the contract. Colonel Bion J. Arnold selected the open areas around Carlstrom Field, Arcadia, Florida, but the Armistice interrupted the entire program. In August of 1919, the project was again activated and 12 aerial torpedoes were shipped, in September, to Carlstrom.

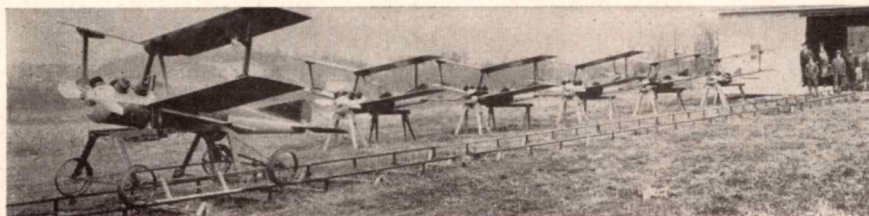
Tests started Sept. 26, and continued through Oct. 28. Nine launchings were made but only one was completely successful. The last flight covered a distance of 19.5 miles, power diving into the target area and disintegrating on the way down. It is interesting to note that a DeHavilland DH-4 chase plane was used for observation.

The gyroscope was essential to the Navy-Sperry and the Army-Kettering aerial torpedoes and remains today the heart of guided missiles. Both developments were born under the pressure of war and both built pilotless missiles intended for operational use but returned to piloted service aircraft to perfect the control system before practical results were obtained.

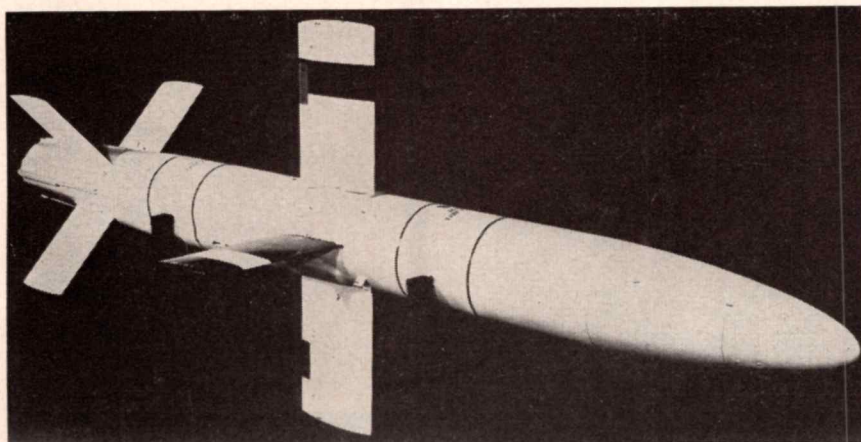
Elementary as they may seem, these aerial torpedoes were the ancestors of today's guided missiles.

END

Kettering Aerial Torpedoes at South Field, Dayton, Ohio in 1918—original site of first tests



MISSILE DIRECTORY



TYPE: Surface-to-Air

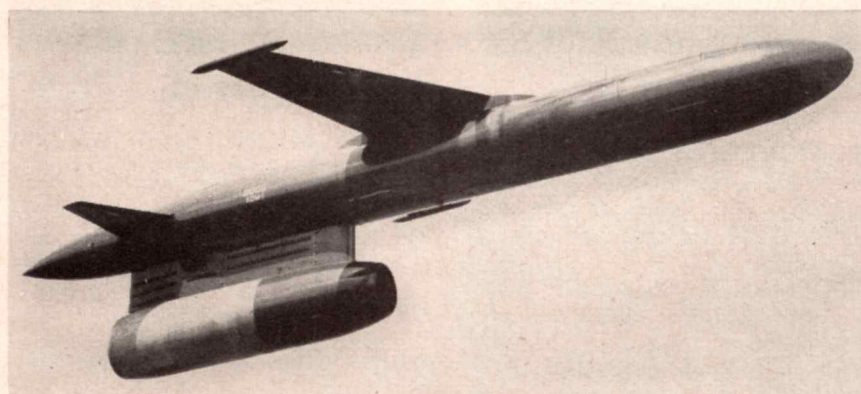
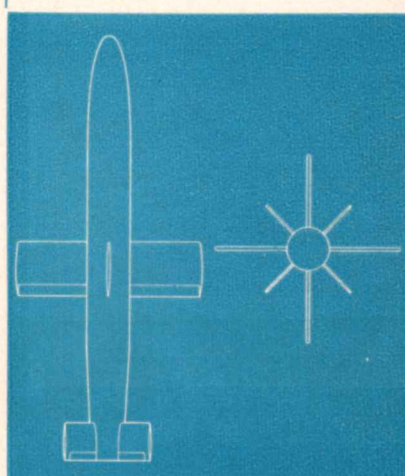
SPECIFICATIONS: Span 6 ft. 5 in.; Length 14 ft. 5 in.; Dia. 15 in.; Weight 1210 lb.; Propulsion Reaction Motors liquid-propellant rocket (red fuming nitric acid and aniline) with solid fuel rocket booster for launching.

PERFORMANCE: Speed M 0.9; Range 10 mi.

GUIDANCE: Semi-active homing.

REMARKS: Developed by Fairchild Guided Missiles Division in 1950, missile is used for training and test work in development of guidance, launching and handling techniques.

FAIRCHILD LARK



TYPE: Target Drone

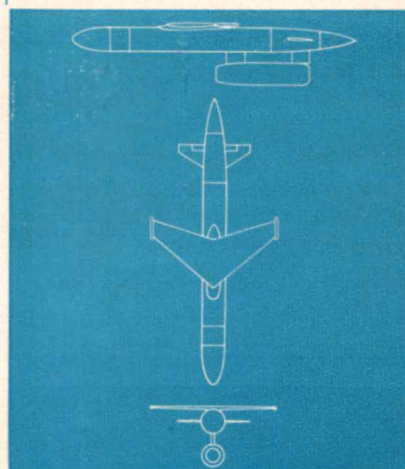
SPECIFICATIONS: Span 6 ft.; Length 22 ft. 2 1/2 in.; Height 4 ft. 8 in.; Gross weight 1835 lb. Propulsion Marquardt ramjet.

PERFORMANCE: Speed 500 mph; Ceiling 30,000 ft.; Range 200 mi.

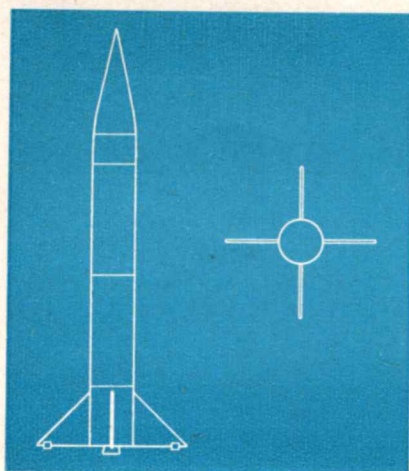
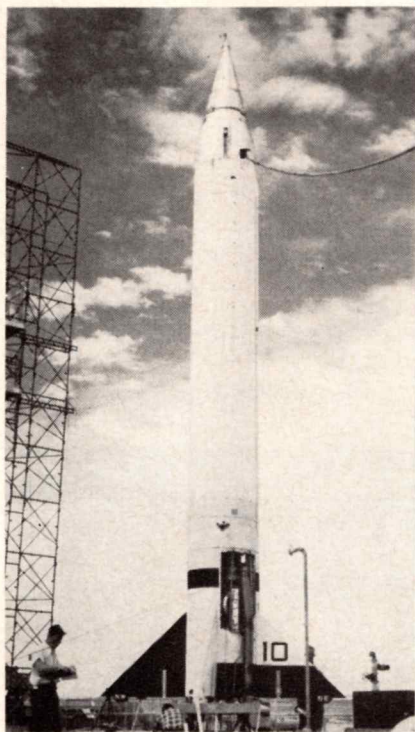
GUIDANCE: Radio command

REMARKS: Air-launched, the drone cruises at pre-set 5-20,000 ft. altitude, executes maneuvers directed from shipboard or control airplane. Parachute recovery system for reuse. Final development form of family of Gorgon types first flown in 1947.

MARTIN PLOVER



MARTIN VIKING



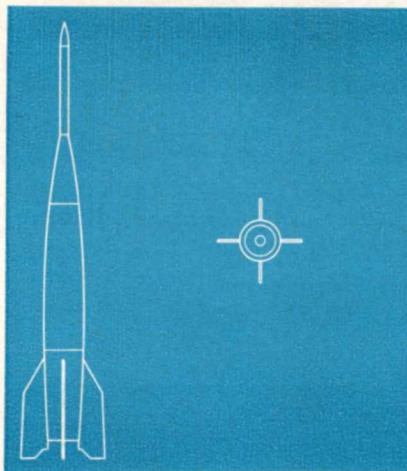
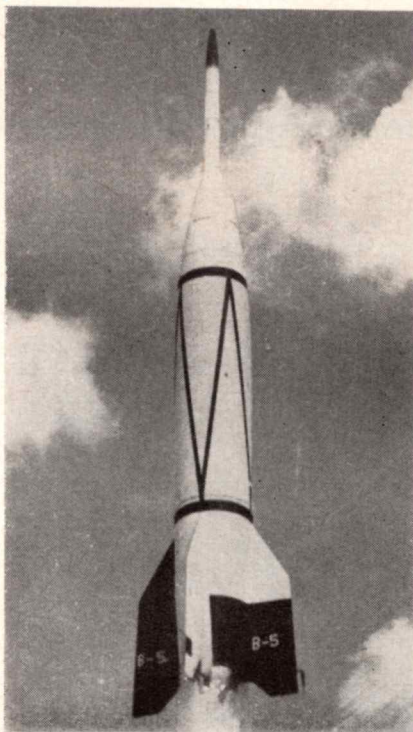
TYPE: Research Missile

SPECIFICATIONS: Length 42 ft.; Dia. 40 in.; Propulsion Reaction Motors (liquid oxygen and ethyl alcohol) 20,000 lb. thrust; Gross weight 15,000 lb. including 700 lb. of instruments.

PERFORMANCE: World's single-stage rocket altitude record of 158 miles during which speed of 4300 mph attained.

REMARKS: Second series of Viking upper atmosphere research missiles. Nos. 10 and 11 are larger in diameter for increased fuel, higher performance. Missiles obtain wide variety of research data on atmosphere for future missile design.

DOUGLAS BUMPER



TYPE: Research

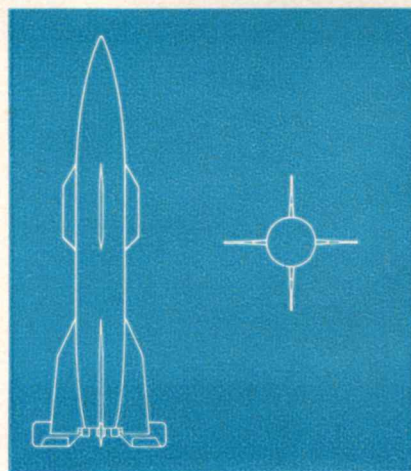
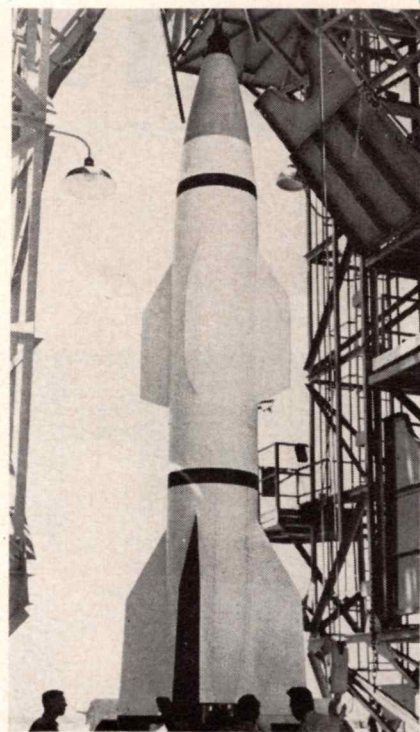
SPECIFICATIONS: Length 62 ft.; Dia. 66 in.; Gross weight 26,895 lb.; Propulsion V-2: liquid oxygen and alcohol; WAC Corporal: nitric acid and aniline.

PERFORMANCE: Speed V-2: 3500 mph; WAC Corporal 2800 mph; Altitude 250 mi.

GUIDANCE: Preset schedule

REMARKS: Project Bumper was series of eight missiles made up of CalTech WAC Corporal mounted in nose of rebuilt German V-2 to investigate mechanics of multi-stage missiles including high altitude firing. Project was joint Douglas-General Electric-Army Ordnance program. On Feb. 25, 1949 a Bumper missile reached 250 mi. altitude.

GENERAL ELECTRIC HERMES



TYPE: Surface-to-Surface

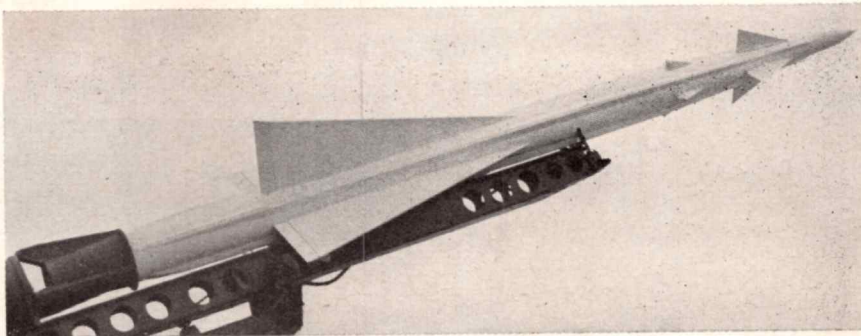
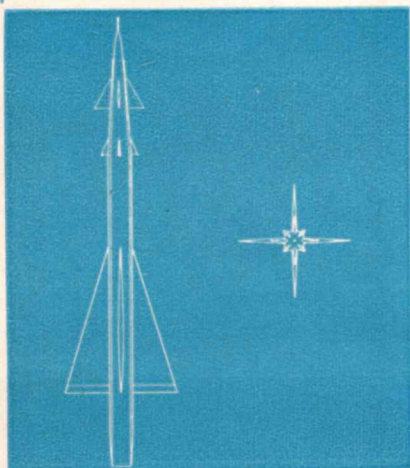
SPECIFICATIONS: Length 25 ft. 7 in.; Dia. 32 in.; Span of fins 7 ft. 8 in.; Gross weight 8000 lb.; Propulsion General Electric liquid-propellant (nitric acid and aniline) rocket.

PERFORMANCE: Speed M 2.0; Altitude 20 mi.; Range 50 mi.

GUIDANCE: Radio command, radar controlled.

REMARKS: Hermes I is original test vehicle shown here; Hermes II is similar but geometrically enlarged to gross weight of about 25,000 lb.; Hermes III is similar but lies between these two with 12,500 lb. gross weight. Extensive development program for development of rocket propulsion and guidance systems.

DOUGLAS NIKE



TYPE: Surface-to-Air

SPECIFICATIONS: Length 20 ft.; Dia. 12 in.; Gross weight 1000 lb.; Propulsion Aerojet liquid-propellant rocket sustainer, solid-propellant booster for launching.

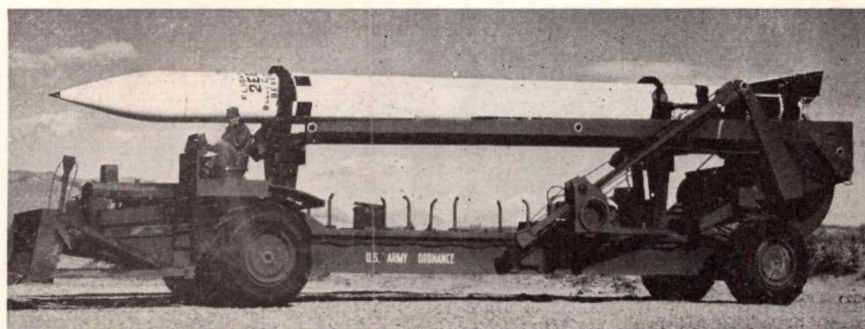
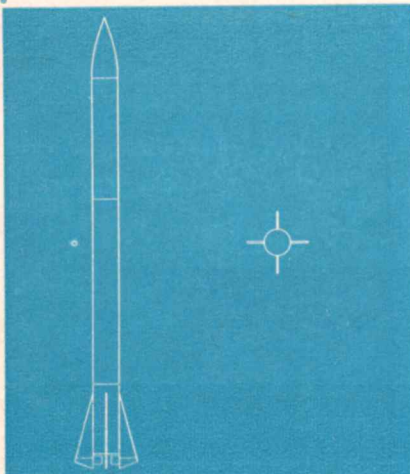
PERFORMANCE: Speed M 2.0; Altitude 75,000 ft.; Range 35 mi.

GUIDANCE: Beam rider with ground

radar illuminated target; radar seeking head.

REMARKS: Production by Douglas, airborne and ground electronics equipment by Western Electric. First combat-ready air defense missile, it is now on duty in batteries near Washington, D. C. and New York City.

FIRESTONE CORPORAL



TYPE: Surface-to-Surface

SPECIFICATIONS: Length 40 ft.; Dia. 30 in.; Gross weight 12,000 lb.; Propulsion Aerojet liquid-propellant rocket.

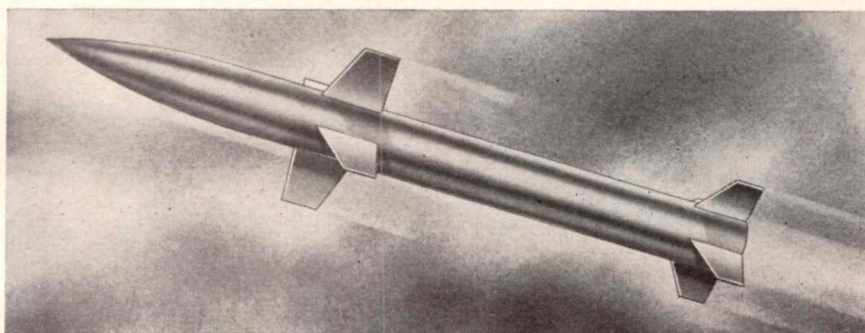
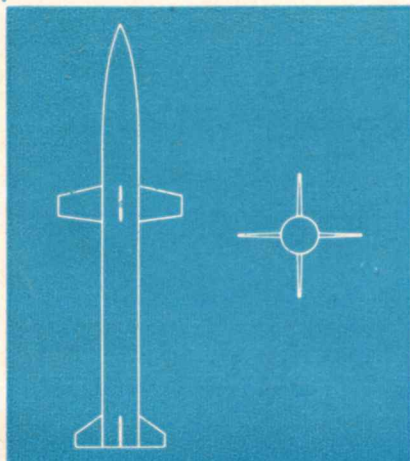
PERFORMANCE: Speed M 3.0; Ceiling 50 mi.; Range 150 mi.

GUIDANCE: Radio command, radar

controlled.

REMARKS: Culmination of 10-year research program by CalTech scientists in Private-Private First Class-WAC Corporal series, tactical missile uses Gilfillan electronic equipment and is in quantity production by Firestone Tire & Rubber Co.

CONVAIR TERRIER



TYPE: Surface-to-Air

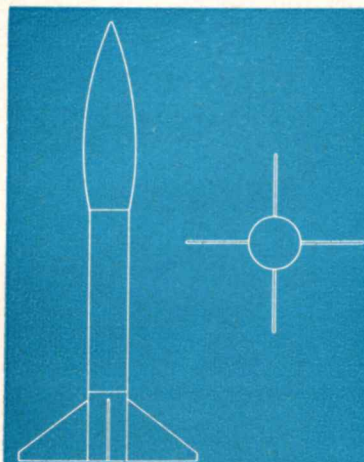
SPECIFICATIONS: Span 4 ft. 1 in.; Length 14 ft. 8 in.; Dia. 12 in.; Gross weight 3360 lb.; Propulsion Aerojet solid-propellant rocket.

GUIDANCE: Radar seeking, beam rider.

PERFORMANCE: Speed M 2.0; Altitude 75,000 ft.; Range 10 mi.

REMARKS: Developed by Applied Physics Laboratory, Johns Hopkins University and in production at new Convair Pomona, Calif. plant since June, 1951.

DOUGLAS HONEST JOHN



TYPE: Surface-to-Surface

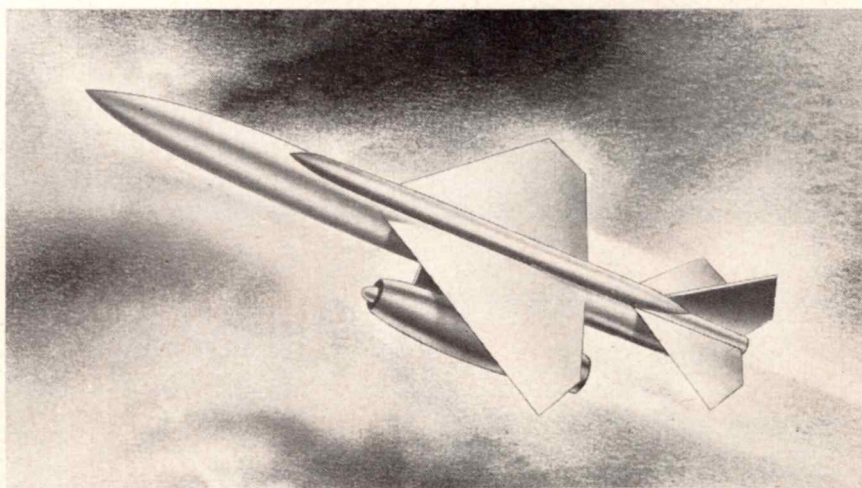
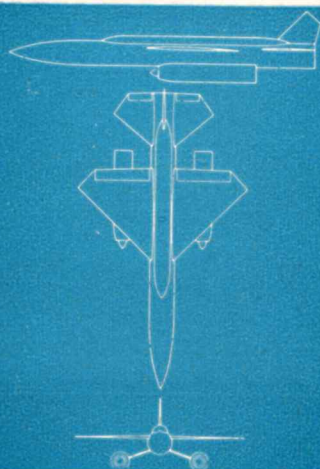
SPECIFICATIONS: Length 28 ft. 2 in.; Dia. 30 in.; Gross weight 10,000 lb.; Propulsion solid propellant rocket.

PERFORMANCE: Speed M 1.5; Range 75 mi.

REMARKS: Unguided artillery rocket, the missile follows an accu-

ately-aimed free flight to target but has increased range and impact velocity. Design began May, 1950; first firing August, 1951 at White Sands Proving Ground. Large production contract signed January, 1953 and now in production at Douglas Santa Monica plant.

BOEING BOMARC F-99



TYPE: Surface-to-Air

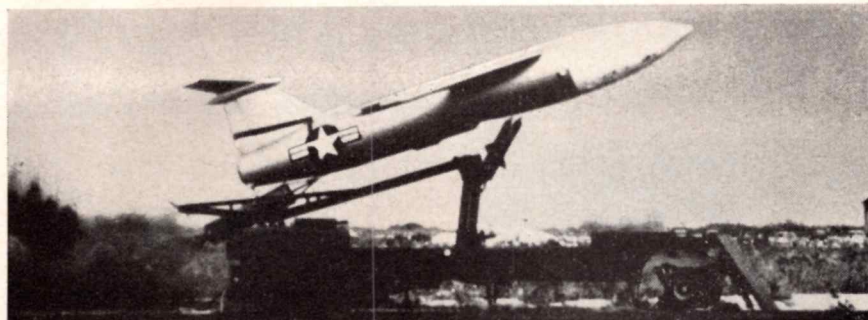
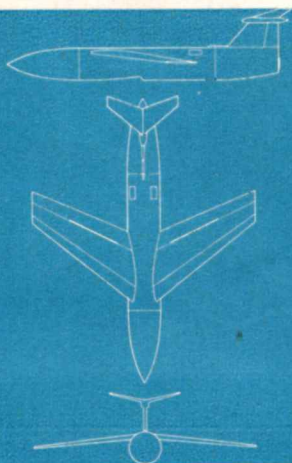
SPECIFICATIONS: Span 36 ft.; Length 66 ft.; Height 16 ft.; Gross weight 8500 lb.; Propulsion two Marquardt ramjet engines plus solid fuel rocket booster in tail.

PERFORMANCE: Speed M 2.0; Altitude 60,000 ft.; Range 50 mi.

GUIDANCE: Radar homing, beam rider.

REMARKS: Pilotless aircraft type, the missile is launched from vertical mount by booster; ramjets provide total power beyond M 1.0. Already in flight test and preliminary production, Air Force designates missile as fighter for interception duties.

MARTIN MATADOR B-61



TYPE: Surface-to-Surface

SPECIFICATIONS: Span 28 ft. 7 in.; Length 39 ft. 6 in.; Height 7 ft. 6 in.; Gross weight 12,000 lb.; Propulsion Allison J33-A-31 turbojet, 4600 lb. static thrust; Solid-propellant booster rocket.

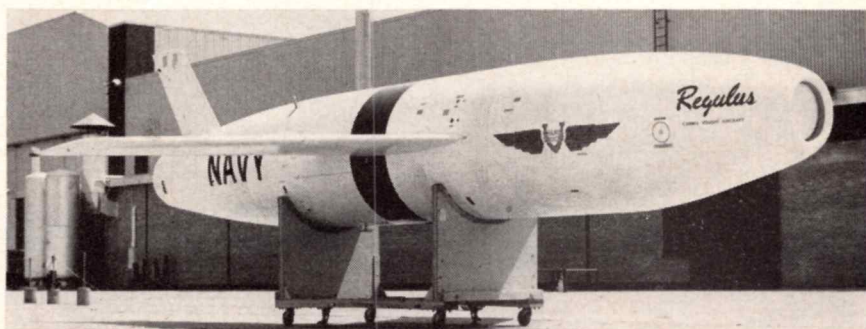
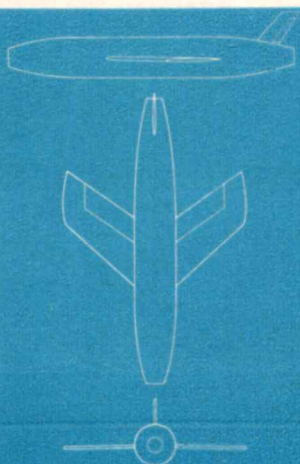
PERFORMANCE: Speed 660 mph; Altitude 45,000 ft.; Range 550 mi.

GUIDANCE: Radio command from

ground station using radar intelligence.

REMARKS: First U.S. tactical missile to be assigned to duty, it is now in service with 1st Pilotless Bomber Squadron in Germany with 69th Squadron being transferred this fall. First firing Jan. 20, 1949 at Holloman AFB, N. Mex. Now in quantity production, it is shipped in seven packages for field assembly.

VOUGHT REGULUS



TYPE: Surface-to-Surface

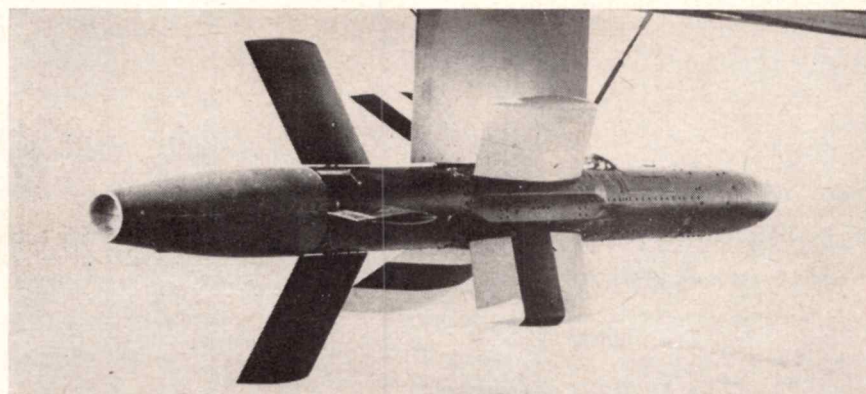
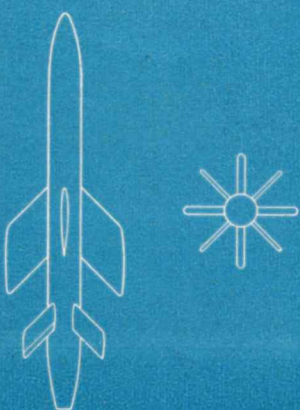
SPECIFICATIONS: Span 21 ft.; Length 32 ft.; Gross weight 14,522 lb.; Propulsion Allison J33-A-10 turbojet, 4600 lb. static thrust, launched by two 1000-lb. solid-propellant booster rockets.

PERFORMANCE: Speed 600 mph; Range 200 mi.

GUIDANCE: Radio direction, radar control, ASW guidance.

REMARKS: Designed for shipboard launching and radio guidance to enemy surface or undersea craft and homed into target. Pilotless bomber uses Vought-developed sandwich structure. Now in quantity production for fleet units.

RYAN FIREBIRD



TYPE: Air-to-Air

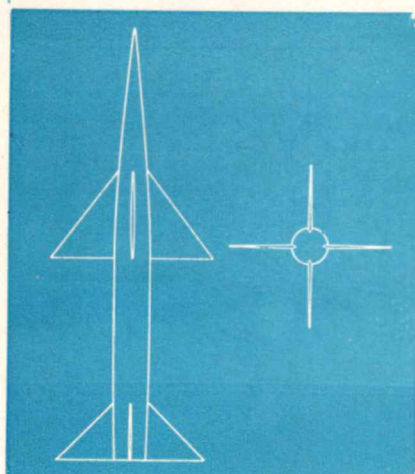
SPECIFICATIONS: Length 7 ft. 6 in.; Dia. 6 in.; Span 3 ft.; Weight 600 lb.; Propulsion solid fuel bipropellant rocket.

GUIDANCE: Radio direction, radar homing.

REMARKS: First Air Force air-to-air

missile, as many as four have been launched simultaneously from underwing racks. Nose contains proximity-fired destructive charge. Production quantity produced in 1950 and missile proved in launching tests at Holloman Air Force Base, New Mexico during 1951-2.

SPERRY SPARROW



TYPE: Air-to-Air

SPECIFICATIONS: Length 8 ft. 3 in.; Dia. 6 in.; Span 2 ft. 3 in.; Gross weight 280 lb.; Propulsion solid-propellant (double base powder) rocket.

PERFORMANCE: Speed M 3.0; Range 5 mi.

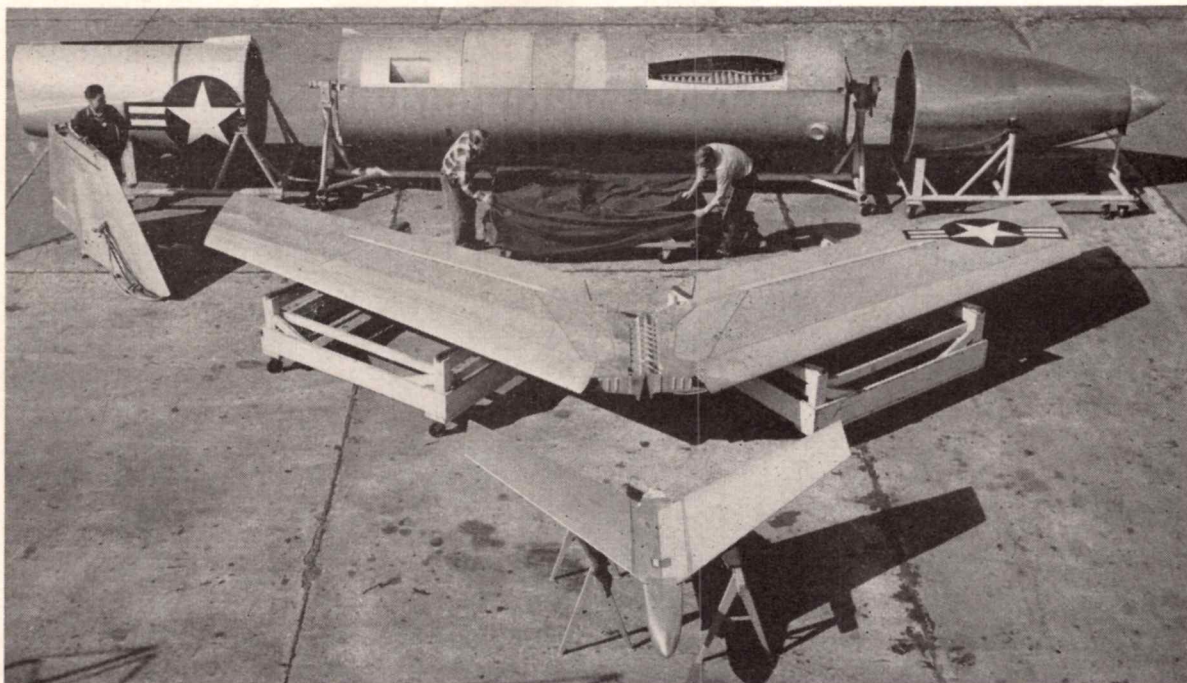
GUIDANCE: Radar beam rider, radar seeking head.

REMARKS: Design began 1947 with

Douglas Aircraft doing airframe, Sperry guidance equipment. Volume production on complete unit under way May, 1954 from new Sperry-Farragut Corp. plant near Bristol, Tenn.

MISSILES CURRENTLY IN DEVELOPMENT AND PRODUCTION

COMPANY	MISSILE	TYPE	SERVICE	ENGINE-PROPELLANT	REMARKS
BELL AIRCRAFT CORP. Buffalo, N. Y.	METEOR	Air-to-Air	Navy	Rocket-liquid	Interim design; 500 lb. wt.; M 3 speed.
	RASCAL B-63 SHRIKE	Air-to-Surface Surface-to-Air	Air Force Army	Rocket-liquid Rocket-liquid	Pilotless X-1 airplane Production at Buffalo plant 1952
BENDIX AVIATION CORP. South Bend, Ind.	LOKI	Surface-to-Air	Army	Grand Central-solid	Barrage anti-aircraft, 3-in. dia., rapid fire
	TALOS	Surface-to-Air	Navy	Rocket-liquid	Anti-aircraft weapon for shipboard use
BOEING AIRPLANE CO. Seattle, Wash.	BOMARC F-99	Surface-to-Air	Air Force	2 Marquardt ramjet	Delta-wing interceptor
CHRYSLER CORP. Detroit, Mich.	REDSTONE	Surface-to-Surface	Army	Rocket-liquid	Giant, 60-ft. long, 5-ft. dia.
CONSOLIDATED VULTEE AIRCRAFT CORP. Pomona, Calif.	ATLAS	Surface-to-Surface		Rocket-liquid	First projected intercontinental missile
	TERRIER	Surface-to-Air	Navy	Aerojet-solid	Quality production, shipboard anti-aircraft
CORNELL AERO. LAB. Buffalo, N. Y.	LACROSSE	Surface-to-Surface	Navy	Allison J33	Experimental unit for guidance development
DOUGLAS AIRCRAFT CO. Santa Monica, Calif.	HONEST JOHN	Surface-to-Surface	Army	Rocket-solid	Unguided artillery rocket, long range
	NIKE	Surface-to-Air	Army	Aerojet-liquid	First in-service U.S. air defense missile
FAIRCHILD GUIDED MISSILES DIVISION Wyandanch, N. Y.	LARK	Surface-to-Air	Navy	Reaction Motors-liquid	Shipboard anti-aircraft defense
	PETREL	Air-to-Underwater	Navy	Fairchild turbojet	Anti-submarine for aircraft, helicopters
FIRESTONE TIRE & RUBBER CO. Akron, Ohio	CORPORAL	Surface-to-Surface	Army	Aerojet-liquid	Very long range artillery weapon
GENERAL ELECTRIC CO. Sydney, N. Y.	HERMES	Surface-to-Surface	Army	General Electric-liquid	Development program, three sizes under test
GRUMMAN AIRCRAFT ENGR. CORP. Bethpage, N. Y.	RIGEL	Surface-to-Surface	Navy	Marquardt ramjet	Design only plus component test
HUGHES AIRCRAFT CORP. Tucson, Ariz.	FALCON F-98	Air-to-Air	Air Force	Rocket-solid	Hughes guidance equipment, M 3.0 speed
THE GLENN L. MARTIN CO. Baltimore, Md.	MATADOR B-61	Surface-to-Surface	Air Force	Allison J33 turbojet	First in-service pilotless bomber, German duty
	ORIOLE PLOVER KDM-1	Air-to-Air Target Drone	Navy Navy	Ramjet Marquardt ramjet	Gross weight 1500 lb., M 3.0 speed Target drone for anti-aircraft shipboard training
NORTH AMERICAN AVIATION, INC. Inglewood, Calif.	VIKING	Research	Navy	Reaction Motors-liquid	World's record altitude of 158 mi. single-stage
	NAVAJO		Air Force	Wright ramjet	Long-range, firing to begin at Patrick AFB
NORTHROP AIRCRAFT, INC. Hawthorne, Calif.	SNARK B-62	Surface-to-Surface	Air Force	Allison J33 turbojet	Swept-wing pilotless bomber in production
SPERRY-FARRAGUT CORP. Bristol, Tenn.	SPARROW	Air-to-Air	Navy	Rocket-solid	First aerial firing from Douglas F3D Skyknight
CHANCE VUGHT AIRCRAFT CORP. Dallas, Tex.	REGULUS	Surface-to-Surface	Navy	Allison J33 turbojet	Production, carrier-launched anti-ship-sub



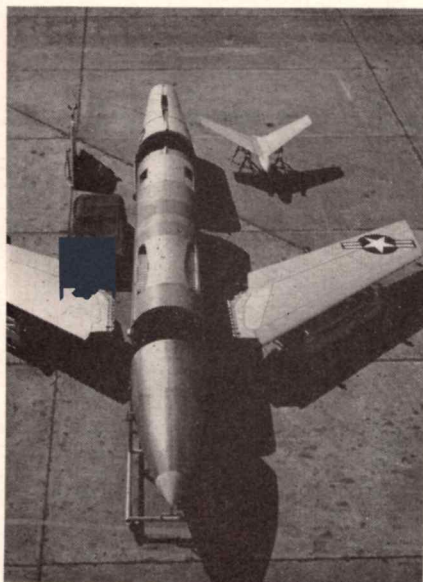
These are the seven basic units in Matador assembly. Cover hides details of belly air intake assembly



missile production

Matadors cannot be flown away from plant, are shipped in component crates for future assembly

INTERCHANGEABLE ASSEMBLY



Arranged in correct position, units are ready for assembly

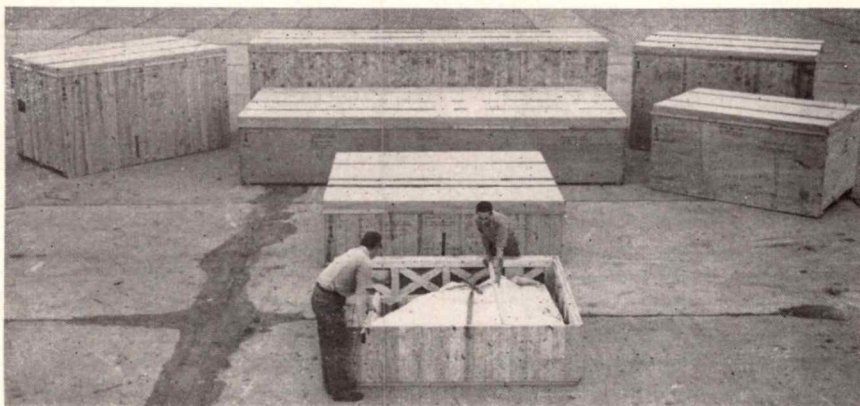
These seven crates can be stored indefinitely for future assembly of the missile.

THE Glenn L. Martin Co. is producing the first aircraft designed for assembly in the field. The B-61 *Matador* pilotless bomber is shipped in seven weather-proof crates and is not assembled until just before launching, which may occur thousands of miles from the plant and even several years after shipping.

This procedure makes complete interchangeability of the assemblies a necessity. This problem is at-

tacked in the original production tooling stage, which must avoid any matched drilling of bolt holes. Instead, identical end-frame drill jigs must be used for adjacent components.

Matador pilotless bombers are now being shipped to the 1st Pilotless Bomber Squadron in Germany and to the 69th Pilotless Bomber Squadron, now at Patrick Air Force Base, Fla., but scheduled for transfer to Germany this fall. **END**



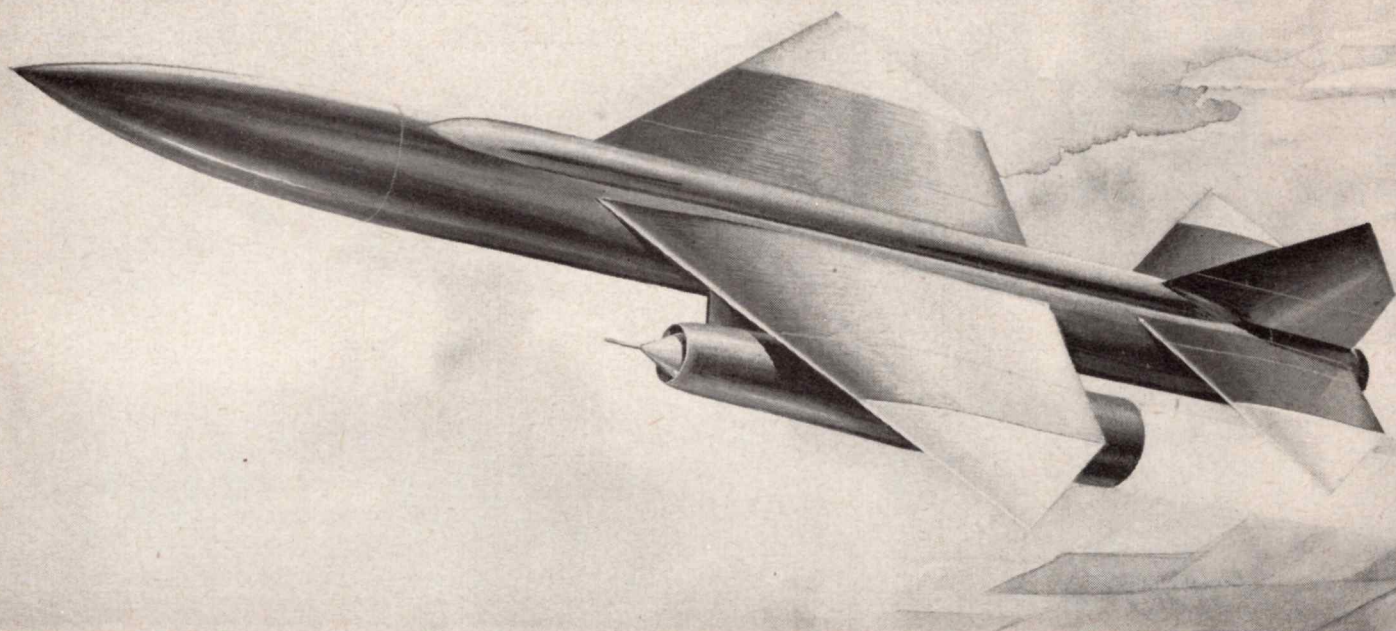
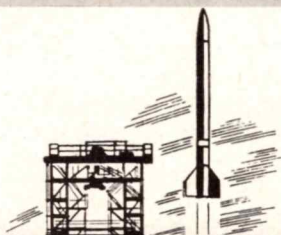


Fig. 1 Boeing XF-99 Bomarc surface-to-air missile



missile propulsion

THE RAMJET POWERPLANT

By MALCOLM HARNED

Chief Technical Engineer, Marquardt Aircraft Corp.

Long possessor of an exclusive range of missile environments, recent improvements in the ramjet have expanded this range significantly

THE guided missile is a new concept in aircraft, and as such requires new concepts in aircraft engines. The principal difference, that each missile's life is limited to one flight without a pilot, removes the old considerations of long life between overhauls, low operating costs, easy maintenance, and good low-speed thrust for landing as well as take-off. In their place are substituted requirements for minimum engine cost, the highest possible thrust/weight ratios, and operation at supersonic velocities.

As a consequence of this change in emphasis, the simplicity and high supersonic performance of the ramjet promise to make it the principal airbreathing engine type used to power guided missiles.

After pioneering developments, relatively little information was released to show what use was being made of the ramjet until the disclosure last year of the Boeing XF-99 *Bomarc* missile shown in Fig. 1. This is a ramjet-powered supersonic interceptor missile, which uses a rocket boost to accelerate it to the operating speed range of the ramjets. This missile is designed to shoot down anything our potential enemies can put in the skies for many years to come.

Excepting these bits of information, ramjet development has been shrouded with the same military secrecy as the development of all other guided missile components. Within these security limits this paper will describe the characteristics of the ramjet and show why

it is uniquely adapted to missile propulsion.

Operation

The feature which makes the ramjet unique among powerplants is that compression is achieved by the engine driving the complete aircraft through the air to obtain ram compression at the inlet. Fig. 2 shows a sketch of a hypothetical supersonic ramjet. Fig. 3 is a schematic which shows the changes in pressure and velocity which would occur for this ramjet operating at Mach 2. The supersonic stream entering the inlet is first decelerated, or diffused, by a conical shock wave produced by the spike of the diffuser and then by a normal shock wave.

Additional diffusion is accom-



TABLE I

FACTOR	TURBO-RAMJET	RAMJET + ROCKET
Cruise Mach No.	2.0	2.0
Gross Weight	25,000	25,000
Launching Method	Horizontal Take-off	Vertical
% Structural Weight	30	25
Tank Weight	10% Fuel Wt.	10% Fuel Wt.
Payload & Guidance	2,000 lbs.	2,000 lbs.
Max. Net Thrust	30,000 lbs. at Mach 1.0	Ramjet 28,000 lbs. at Mach 2.0 Rocket 35,000 lbs.
Powerplant Wt.	10,000 lbs.	Ramjet 1,700 lbs. Rocket 900 lbs.
Time to climb to 60,000 feet	2 1/2 minutes (no taxi time)	2 minutes
Range	190 miles	210 miles

plished subsonically in the expanding annular passage. This deceleration of the airstream efficiently converts the kinetic energy of the supersonic stream entering the inlet to pressure inside the diffuser. Fuel is added to the air and burned in the combustion chamber, expanding the gases. The hot gases are then exhausted through a supersonic nozzle at the exit to produce a jet of considerably greater velocity than that of the incoming air.

This change of momentum produces the thrust reaction in the same fashion as all other jet powerplants. The source of thrust can be readily seen by visually integrating the internal pressures acting in an axial direction, which

provides a resultant thrust in the forward direction.

This use of ram compression defines the speed range in which the ramjet can be used efficiently. The thermal efficiency of any internal combustion powerplant is determined largely by the compression ratio (or expansion ratio) as shown in Fig. 4. Along the top of the graph are indicated the equivalent flight Mach numbers corresponding to the compression ratios plotted below. It is evident from Fig. 4 that the ramjet cannot have ram compression ratios and, therefore, thermal efficiencies as high as other air-breathing powerplants, until its flight Mach number reaches the neighborhood of Mach 2. Then its ram compres-

sion ratio (about 7) becomes of the same order as that of other aircraft powerplants. It can also be seen from Fig. 4 that the ramjet is a thermally inefficient powerplant at Mach numbers below unit 1.

The use of ram compression leaves the ramjet with no static thrust. This provides a difficult starting problem, since, instead of starting a mechanical compressor within the engine, we must move the whole aircraft.

Performance

The guided missile of the future must fly at supersonic speeds if it is to be effective, since subsonic missiles are quite vulnerable to weapons existing today, and would be sitting ducks for the weapons being developed. The thrust re-

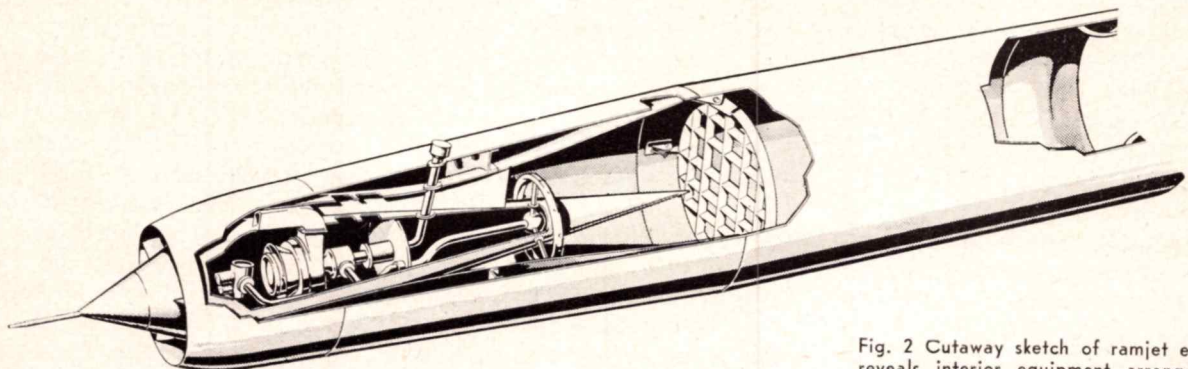


Fig. 2 Cutaway sketch of ramjet engine reveals interior equipment arrangement

quired to propel an aircraft of a given weight is proportional to the square of the speed and inversely proportional to the lift-to-drag ratio. The lift-to-drag ratios obtainable at supersonic speeds are in the range from two to five, which is in sharp contrast to the ratio of 20 which can be obtained at subsonic velocities. This means that increasing the speed from Mach 0.9 to 3.0 would require approximately 60 times the thrust or 200 times the power. With the low ratio of lift-to-drag, it is obvious that we cannot accomplish much by increasing the powerplant size, and it becomes apparent that the ratio of net thrust to weight is our first important engine criterion. (Net thrust is

structures is usually proportional to the cube of the basic dimension and the dynamic pressure. However, ramjets are not usually scaled in length in proportion to their diameter, since the combustion length can remain nearly constant. In addition, as the diameter increases the efficiency of the structure can usually be increased, therefore, a better approximation for the ramjet is:

Weight (W) equal to constant (K) times Diameter (D) squared times dynamic pressure (q) or $W = KD^2q$. Since thrust coefficient (C_t) is defined as thrust (F) divided by dynamic pressure and cross-sectional area (A) or $C_t = F/qA$, then $q = F/C_tA$. We can substitute for q and since A is

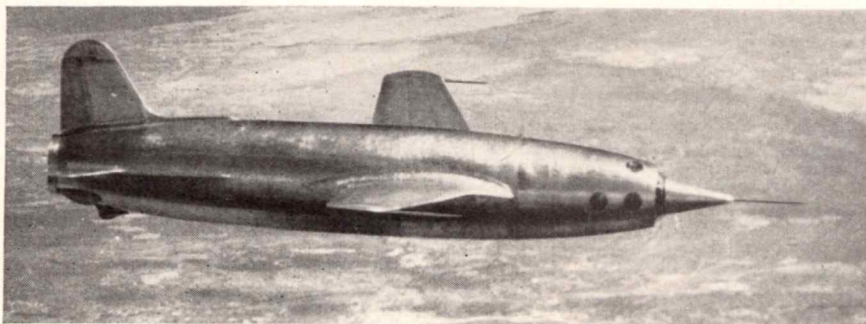


Fig. 8 French Leduc two-place ramjet-powered research airplane

defined as the net propulsive force including the effect of all drag, both internal and external, for which the engine is responsible.)

The ramjet effectively attacks this problem of achieving high thrust/weight ratios by eliminating moving compressors and taking advantage of the kinetic energy available in the airstream moving at high velocity relative to it. The maximum net thrust coefficient available from a nacelle type ramjet engine is illustrated in Fig. 5. Thrust coefficients are provided both for a completely variable geometry engine and for three fixed geometry engines designed for Mach 1.5, 2.3, and 3.5 respectively.

An approximation of the thrust/weight ratio as a function of Mach number can now be determined using these coefficients. The weight of aerodynamically loaded similar

proportional to D^2 obtain

$$W = K \frac{F_{\max}}{C_t}$$

In order to determine the constant of proportionality we shall use the Marquardt XRJ-30-MA-8 subsonic ramjet which weighs 130 lb. and produces 1300 lb. maximum thrust at a coefficient of 0.5. Substituting

$$130 = K \frac{1300}{0.5}$$

and solving for K

$$K = .05$$

Therefore we shall use as our weight

$$W = .05 \frac{F_{\max}}{C_t}$$

This approximate weight formula is for continuously operating engines where the pressure loading

at maximum thrust designs the engine structure.

Now a plot of thrust per unit weight as a function of Mach number can be readily drawn as is shown in Fig. 6. Although this curve is very approximate, it does give an idea of the enormous increase in power per unit weight being made available for high speed aircraft. Comparable curves for the other principal types of powerplants are also included. (Turboramjet is defined as combination of diffuser, turbojet, and afterburner packaged in nacelle.) This comparison shows that the ramjet is a very attractive powerplant at all speeds from Mach .6 up from the weight standpoint, being surpassed only by the rocket. The performance comparison is based on having all powerplants in complete nacelles with all necessary fairing, diffusers, propellers or whatever is involved in producing thrust with the engine weight including the complete assembly. The net engine thrust used includes the effect of external drag, propeller efficiencies, diffuser losses, etc. Data for piston engines are based on currently available engines. The turboramjet, turbojet, and rocket performance is based on current engines in the subsonic range and extrapolated into the supersonic range using NACA data, from Ref. 1, corrected for nacelle drag and weight. (This chart represents the best unclassified information known to the author; however, appreciable improvements in all jet powerplants may be expected with future development.)

To complete the performance picture, the specific fuel consumption of the ramjet is compared with the other powerplants in Fig. 7. A previous figure (3) showed the increase of thermal efficiency with increasing ram compression ratio. This relationship is reflected in the shape of the ramjet SFC curve where, at Mach numbers above 2.0, the ramjet compression ratio and, hence, thermal efficiency, begins to exceed those of other air-breathing powerplants, thus causing the ramjet to have the lowest SFC. Conversely, at Mach numbers below 1.0, where the ramjet compression

ratio and thermal efficiency is very low, the SFC is quite excessive.

The limit of Mach 3.0 shown here for the turboramjet is the result of the temperature limitation imposed by the turbine blades. The stagnation temperature of the supersonic stream becomes so great that insufficient temperature rise through the burner can be achieved without burning out the turbine blades.

Reliability

Although reliability has always been an item of extreme importance in aircraft powerplants, the bugaboo of complexity that has been ushered in with supersonic missiles has placed an even greater emphasis on it. Here is where the ramjet offers a most important potential contribution in that it has virtually eliminated moving parts. A complete supersonic ramjet engine capable of producing well over 100,000 hp. can be built with only half a dozen moving parts, including the fuel pumping system and a completely automatic fuel control system, incorporating flight speed regulation and altitude compensation. It is significant that none of these moving parts is in contact with hot combustion gases, which is not true of any other air-breathing powerplant. Compare this with the elaborate machinery involved

in a modern 3000 hp. piston engine which contains over 250 moving parts. Even the gas turbine engine, which achieved a significant reduction in complexity, usually still has over 40 moving parts in the engine with from several hundred to several thousand blades assembled on the rotor. In addition, a very intricate electronic or hydraulic control system is necessary.

The importance of this simplification can be readily grasped if you assume you are trying to perfect a missile with a thousand component parts. If the components are subject to one out of a hundred failures, the aircraft will have less than a 0.1 percent probability of working. Even if the components are perfected to the 1 out of a 1000 point, there will still be only a 37 percent probability of success; however, if we cut the number of critical components in half we raise the probability of success to 61 percent which approaches the realm of practicality.

Cost

In order to be a successful weapon, the guided missile must obviously be cheap enough to be expendable. Since powerplants are usually among the most expensive components, every effort must be made to minimize their cost. Past experience has indicated

that all types of high performance aircraft engines cost approximately the same to manufacture in dollars per pound of weight. Looking back at Fig. 6, it is now apparent that we will obtain the most thrust per dollar from the rocket with the ramjet running a close second at high Mach numbers.

Since each missile only uses one load of fuel and most fuels cost less than 1/100 as much per pound as airframe, the cost of fuel becomes a secondary consideration. However, the space and airframe required to carry the fuel is still a very important factor in determining missile size and cost. From this standpoint, the ramjet-powered missile with a jettisonable rocket booster appears to promise minimum cost for the following reasons:

1. The rocket and ramjet are by far the lightest and, therefore, the cheapest powerplants.
2. At supersonic speeds above 2.0, the ramjet provides the lowest obtainable specific fuel consumption; therefore, the cruising missile would have the lightest possible engine and would thus require the minimum volume of fuel.
3. The jettisonable boost, since it would be discarded at the end of the initial acceleration, would not compromise the basic missile design and could be constructed

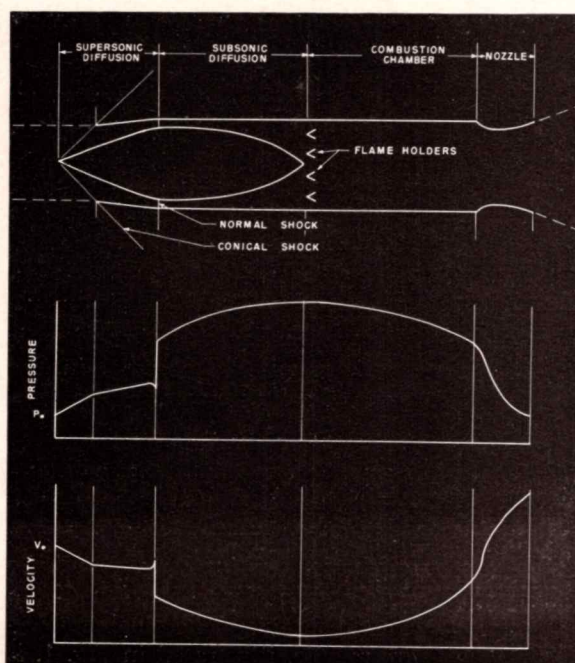


Fig. 3 Changes of pressure and velocity through ramjet operating at Mach 2.0

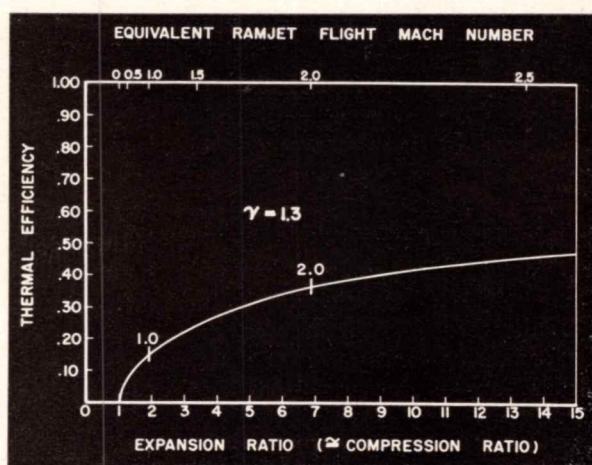


Fig. 4 Plot of thermal efficiency vs compression ratio for ramjet engine

quite inexpensively. In this way the rocket motor's high specific fuel consumption does not penalize the over-all system.

Installation

The ramjet engine is undoubtedly the most flexible air-breathing engine available, since it does not have a mechanical compressor. The ramjet can be built as a nacelle unit for strut mounting, as shown in Fig. 1, or it can be made an integral part of the aircraft as was done with the Leduc ramjet-powered airplane as shown in Fig. 8. (Although the French-built Leduc has a pilot, he is buried in the diffuser island so that it looks like a missile configuration.) The integral engine could also have a scoop intake at the rear of the fuselage instead of ducting the air aft from the nose.

The merits of the nacelle versus the integral installation are debated for the ramjet in much the same way as for the turbojet, with

tion is that the engine is much easier to develop in this form where the complete missile doesn't have to be installed in the test facility.

The information above has covered the performance and characteristics of the ramjet as they apply in general to guided missiles. The remainder of the paper will consider the application to specific types of missiles:

Air-to-Air Missiles

Small, rocket-powered guided missiles are now being used as armament for interceptors. However, their range is necessarily limited by the rocket's high specific fuel consumption. When longer ranges are demanded, a rocket-boosted ramjet configuration should appear attractive.

Since the F-100 has demonstrated its practicability as a supersonic interceptor, the novel possibility of launching ramjet missiles at supersonic speeds with

where R = range

K = constant determined by units involved

V = velocity

SFC = specific fuel consumption

$\frac{L}{D}$ = lift to drag ratio

$\frac{W_1}{W_2}$ = ratio of fueled weight to empty weight of the aircraft.

V

The ratio, $\frac{V}{SFC}$, is primarily de-

termined by the powerplant and, since range is directly proportional, is known as the propulsion range parameter.

Fig. 9 provides a chart comparing the propulsion range parameter for the principal powerplant types. This clearly illustrates the superiority of the ramjet for long range at high supersonic Mach numbers, particularly when it simultaneously offers the maximum thrust/weight ratio.

Air-to-Ground Missiles

This category can cover everything from large bombardment missiles to short range ground-support missiles, i.e., anything that can be hung on an airplane. All of the features of the ramjet which make it attractive for the missile types discussed above apply to this category. As in the case of the air-to-air missile, if the launching airplane has a high enough speed, the rocket boost can be completely eliminated.

Fig. 10 shows the Martin KDM-1 target drone which is powered by a 20-in. dia. Marquardt ramjet. This is an air-launched subsonic drone which requires no booster. If a war had taken place two to four years ago, the KDM-1 might have been placed in service as a missile. However, because of its subsonic speed, it will be obsolete in the event of a future war.

Interceptor Missiles

The development of first the atomic bomb and now the hydrogen bomb has resulted in a heavy emphasis on interceptor missile development for protection of the United States. The Boeing *Bomarc* missile, illustrated in Fig. 1, is

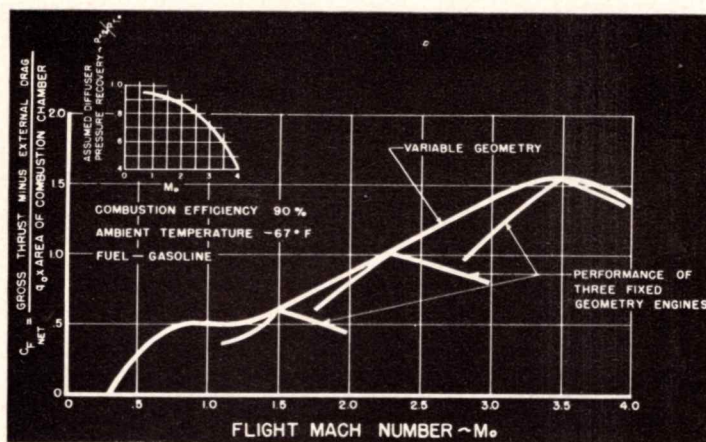


Fig. 5 Thrust coefficients for ramjet engines at various flight Mach numbers

just as much difficulty in arriving at a clear decision. The integral installation offers the minimum over-all drag; however, the engine performance extracts a penalty either for losses through a long duct or for boundary layer removal at the aft scoop. The nacelle installation helps isolate the missile components from engine vibration and makes a switch from one engine model to another relatively easy.

Probably the most significant advantage for the nacelle installa-

no rocket boost becomes practical. This would represent very close to an optimum missile configuration.

Long-Range Bombardment Missiles

In evaluating powerplants for long range applications, the classic Breguet range equation is the best guide to follow. Derived for jet propulsion, it is as follows:

$$R = K \frac{V}{SFC} \frac{L}{D} \log_e \left(\frac{W_1}{W_2} \right)$$

the first weapon in this category to be disclosed, and as pointed out previously, uses ramjet power with rocket boost.

This combination of rocket and ramjet appears to offer an ideal propulsion system for interceptor missiles because:

1. The rocket boost is needed to provide for a quick, vertical launching, since we can't provide runways for all missile installations.

2. For effective interception, the missile must travel much faster than its prey in order to allow time for detection, launching, seeking and closing on the target before it gets out of range. This dictates high supersonic Mach numbers (above 2.0) since bombers capable of Mach .9 are commonplace, and transonic, if not supersonic, bombers are certainly under development by our potential enemies. In this speed range above Mach 2.0, the performance chart indicated that there was no real competition for the combination of high thrust/weight ratio and low SFC offered by the ramjet.

3. In order to provide adequate protection, these missiles must be cheap and plentiful; therefore the low cost of the rocket and ramjet engines is a very important factor.

In order to better illustrate the comparison between the combination of ramjet plus rocket, a simplified comparison of two hypothetical missiles is presented

in Table 1. (This study was made using powerplant data presented in this paper with airplane characteristics derived from Ref. 2.) The study was made at Mach 2.0, which is the lowest Mach number at which the ramjet really becomes competitive, and the rocket was not jettisoned, in order to make the aircraft more directly comparable. This comparison indicates that the two missiles have approximately the same performance and the same gross weight. The rocket-ramjet combination has the disadvantage of carrying an oxidizer as well as fuel, but has simple fixed geometry engines. The turboramjet would require both a variable geometry diffuser and a variable area exit nozzle.

The item of particular significance in this study is that the total powerplant weight for the rocket plus ramjet is only one-fourth that required for the turboramjet. Since the fuel costs are almost negligible, this means that we are obtaining our propulsion system to accomplish the same job for one-fourth the price.

In addition, if the rocket and its tanks were jettisoned at the end of the boost, a very substantial increase in range would be possible for the ramjet-powered missile. Increasing the flight Mach number would also increase the superiority of the ramjet-powered version.

Conclusion

Summarizing, the ramjet is uniquely adapted to the propulsion of supersonic guided missiles because in the Mach number range between 2.0 and 4.0, it offers the minimum specific fuel consumption, the highest thrust/weight ratio and the minimum cost of any air-breathing powerplant. In addition, its basic simplicity offers the maximum potential reliability. The one serious drawback is its lack of static thrust, but, when teamed with a rocket booster, the resulting propulsion system provides the guided missile with the additional benefits of fast vertical take-off and rapid acceleration to supersonic speeds which appear to be essential to a successful missile system. Therefore, it appears reasonable to predict that the development of guided missiles and ramjets will be a parallel effort, with the ramjet taking its place as the principal air-breathing engine for missile propulsion.

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1. Performance and Ranges of Application of Various Types of Aircraft Propulsion Systems - NACA TN-1349, August 1947.
2. The Airplane Growth Factor and How to Control It-Ivan H. Driggs, Aeronautical Engineering Review, September 1952.
3. Application of the Ramjet to Aircraft Propulsion, Malcolm Harned, Aero Digest, February 1953

Fig. 6 Comparison of ratios of thrust to weight for aircraft engine types

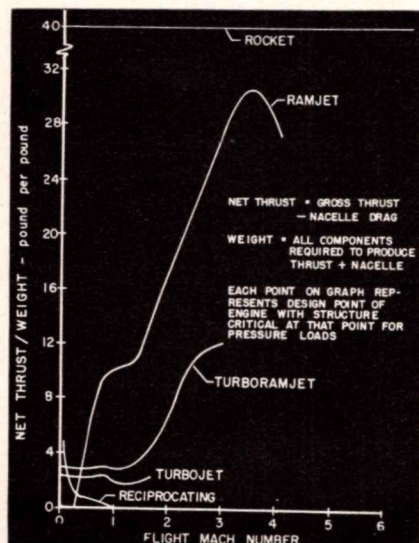


Fig. 7 Comparison of specific fuel consumption of ramjet with other types

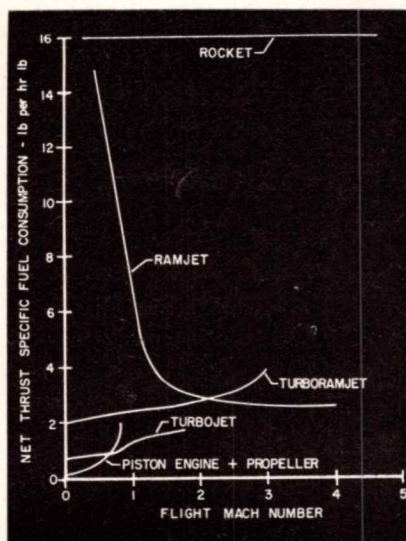
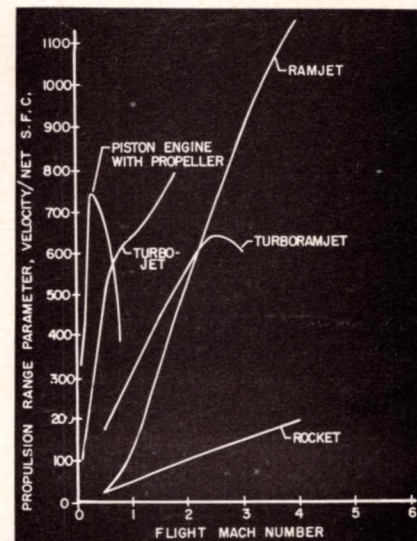


Fig. 9 Propulsion range parameter for various engine types





RYAN FIREBEE

By JOHN LENT

Ryan Aeronautical Company

First comprehensive technical analysis of pilotless aircraft reveals details of this promising new vehicle

RUGGED construction and design simplicity, permitting rapid assembly and easy maintenance, are the primary characteristics of Ryan's new *Firebee* pilotless jet target drone.

Constructed in five major assemblies with simple four-point attachments and self-aligning bolts, the drone can be fully assembled by two or three men in little more than an hour.

The *Firebee* target is capable of near-sonic speeds and has similar performance characteristics to current American jet fighter aircraft. Remotely controlled from the ground, it can maneuver at varying speeds and altitudes, and offers a worthy challenge to the skill of gunnery experts and accuracy of guided missiles.

Need for the *Firebee* was dictated by the rapid advance of guided missile projects, the development of more efficient radar-controlled anti-aircraft artillery and the demand for more speed in military aircraft.

Conceived a few years after World War II when the Government requested manufacturers to study the possibilities of constructing a high speed, high altitude recoverable target, the drone was designed for anti-aircraft and aerial gunnery training, for use in combat plane interception problems and in guided missile target work by Army, Navy and Air Force units. First contract for production *Firebees* was placed last year, first non-powered glide flight tests were made in the spring of 1951, and the first powered flights were in the summer of that year. An intensified test program under the technical cognizance of the U. S. Air Force's Air Research and Development Command followed.

Since each of the services has its own preferred method of launching, *Firebees* have been launched from the ground in both rail and zero-length launches as well as

from the belly and wings of twin-engine mother aircraft.

Somewhat less than half the size of present-day jet fighter aircraft, the drone is a mid-wing, all-metal pilotless aircraft with sharply swept-back wings and tail surfaces. The 1800-lb. airframe has a 12 ft. span, 18 ft. length, and is 6 ft. high.

A Fairchild J-44 turbojet engine of approximately 1000 lb. thrust has powered the target in most of its flights. The engine is 6 ft. long, 22 in. in diameter and weighs 300 lb.

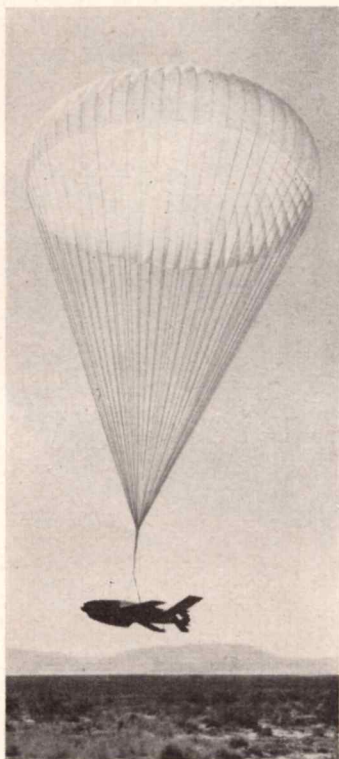
Thanks to its rugged construction, impact damage to the *Firebee* following parachute recovery is usually minor.

Construction is aluminum, magnesium and stainless steel in five major assemblies—fuselage, nacelle, wing, empennage and parachute container (tail cone). The complete target is shipped from the

Ryan factory in a group of five containers weighing 2,500 lb.

Fuselage is of semi-monocoque construction with formed magnesium and stainless steel skin, dural longerons and dural and magnesium frames. The lower forward fuselage section provides for the attachment of the nacelle which houses the engine and engine accessories. A streamlined bullet-shaped fairing is fitted over the engine accessory section when the target is ready for testing or flight.

The nacelle is also semi-monocoque construction with formed magnesium skin on dural longerons and frames. Stainless steel is used in all areas of engine heat. The nacelle is attached to the fuselage at four points with the two forward fittings acting as hinges to permit ready access to the engine without removing the nacelle from the fuselage. Complete with engine installed, the

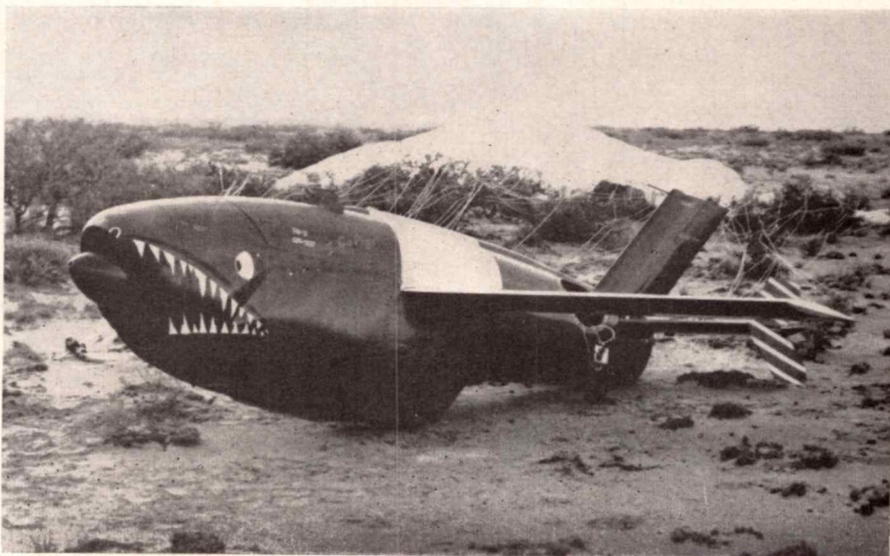


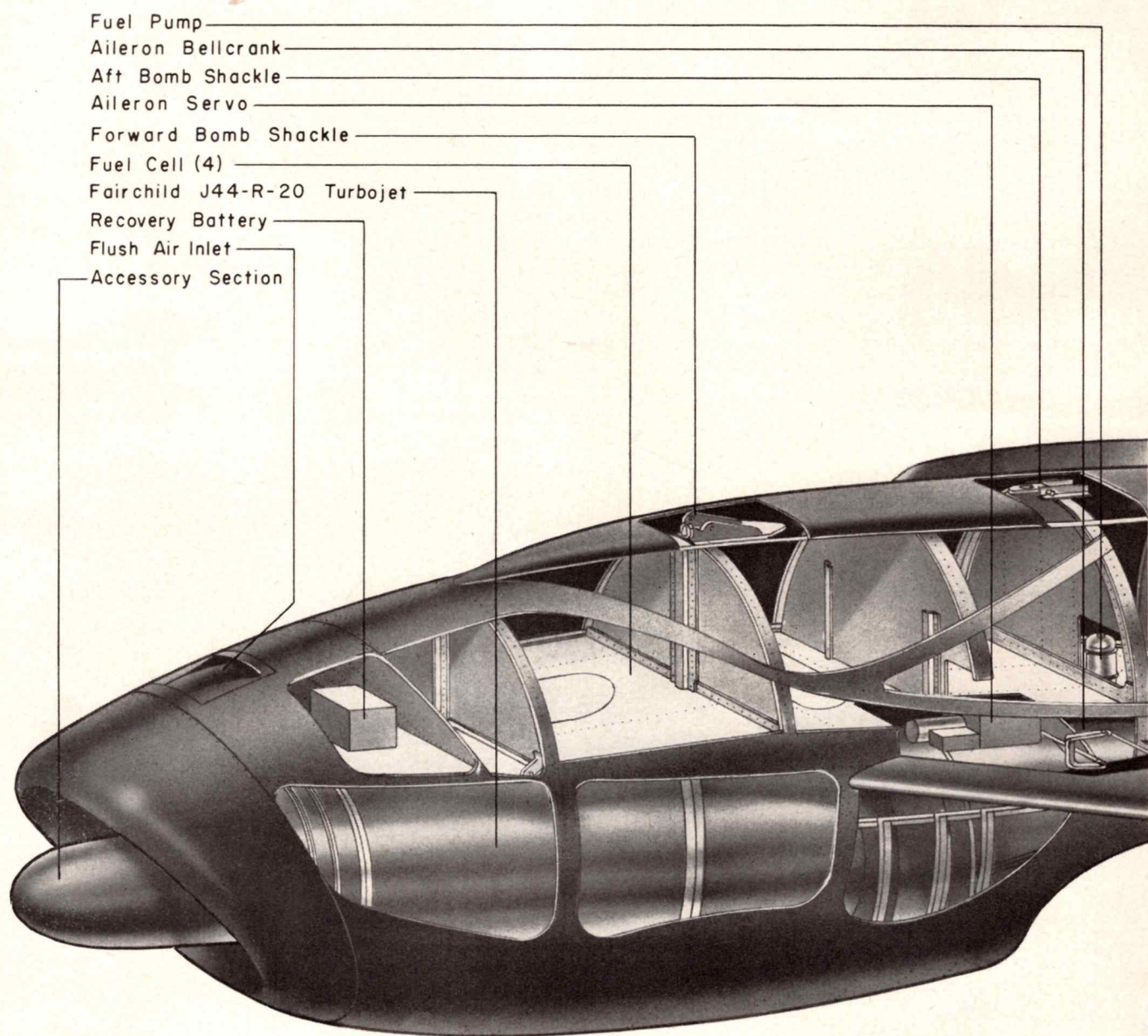
Giant parachute lowers spent Firebee to ground without damage

Spent Firebee, lowered by parachute, displays no damage, is ready for re-launching

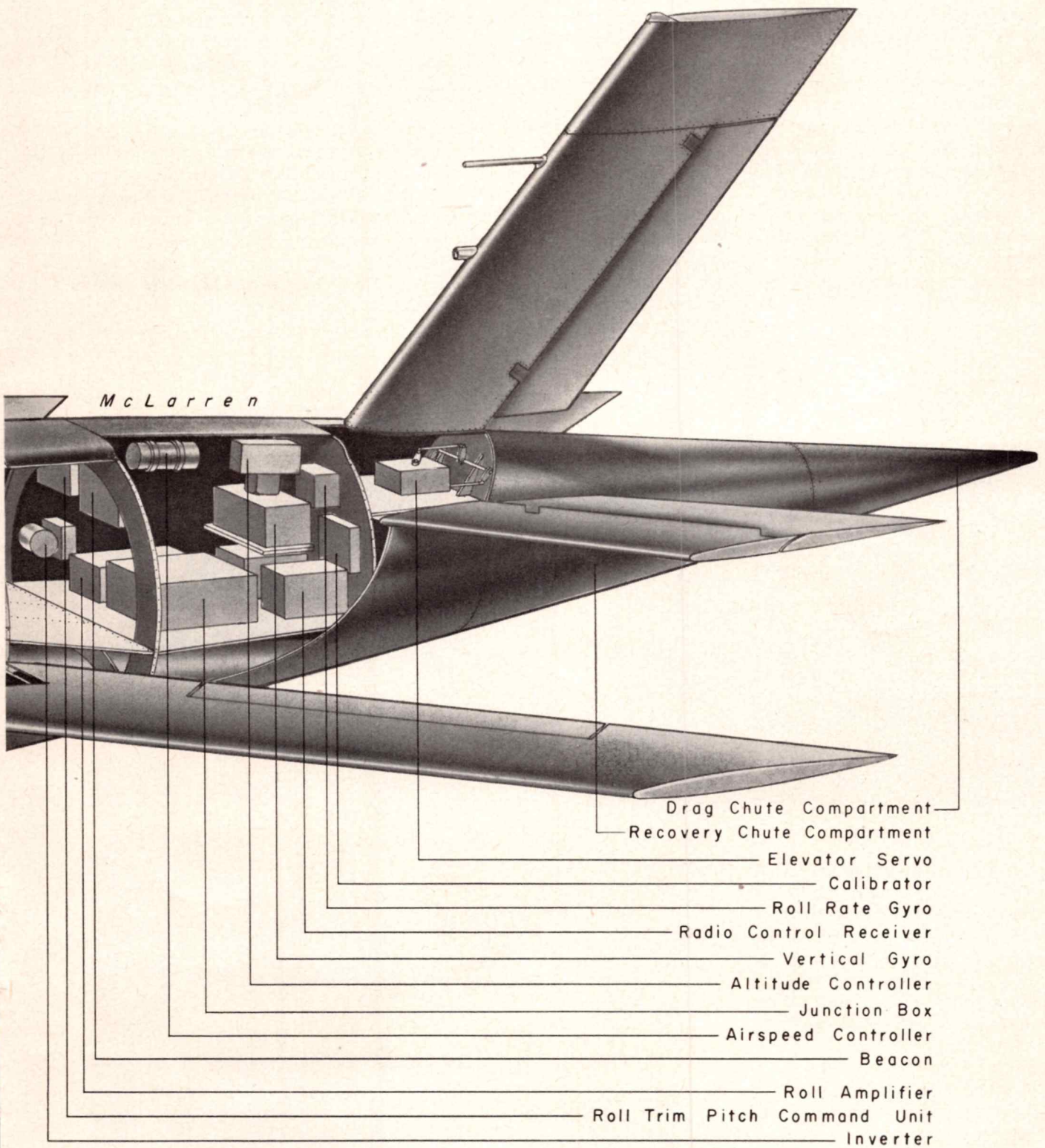


Evidence of cost saving is this record of five safe recoveries by a Firebee in test program





RYAN FIREBEE



nacelle weighs only 500 lb.

The full cantilever wing is unusual in that no ribs are provided in the wing panels other than at the root and tips of the outer panels. The right, left and center panels are a single manufactured unit. The outer wing tips are removable and easily replaceable. They are constructed of light magnesium skin on magnesium spars and are attached to the outer panels of the wing by means of piano hinges on the upper and lower surfaces. The main and center panels are of heavy gauge aluminum alloy skin with three 24-ST spars.

Empennage is semi-monocoque construction with formed magnesium skin, dural magnesium frames and a stainless steel deflector plate. Provision is made for the attachment of the tail group as well as the two section tailcone

developed a two-stage parachute recovery system to decelerate the drone from speeds up to 600 mph. and lower it safely to the ground without harm to the delicate equipment inside. The five foot drag chute and the 70-ft. main suspension chute flare out from the tail cones at the command of the remote control operator. In the event of a target hit, engine failure, or loss of radio wave carrier from the remote control station, the recovery system operates automatically.

In many respects, the problems involved in the development of the *Firebee* were greater than those in designing a conventional man-carrying jet plane. In addition to the normal aerodynamic factors, Ryan engineers had to cope with the eccentricities of a remote control system, an autopilot system and the parachute recovery system.

The target is controlled by com-

mand signals which are transmitted from the ground to the drone by means of a black box containing stick and switches to govern the engine speed and other flight conditions. The command control system installed in the target receives instructions and channels the signals to the proper control surfaces. From the ground remote control station, the target drone can be flown out-of-sight and at high altitudes while being tracked by electronic devices.

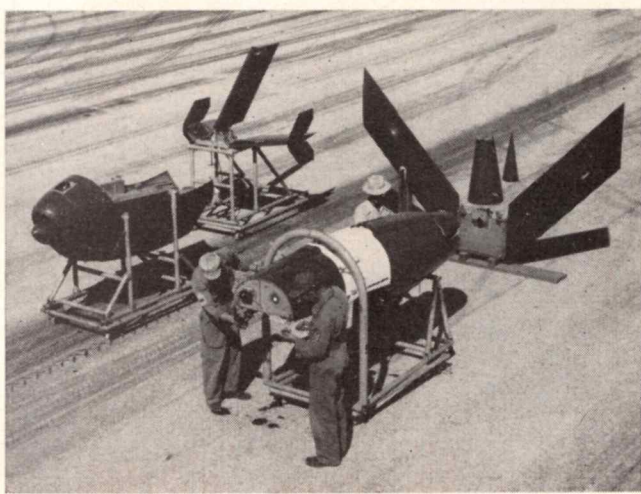
Currently the *Firebee* is involved in two separate test programs at Holloman Air Development Center. With the research and development program conducted by the Ryan test group nearing completion, the drone is in final test phases also for the Air Force Operational Test Center group from the Air Proving Ground Command.

END

Firebee is suspended from special rack for "piggy back" delivering to target vicinity



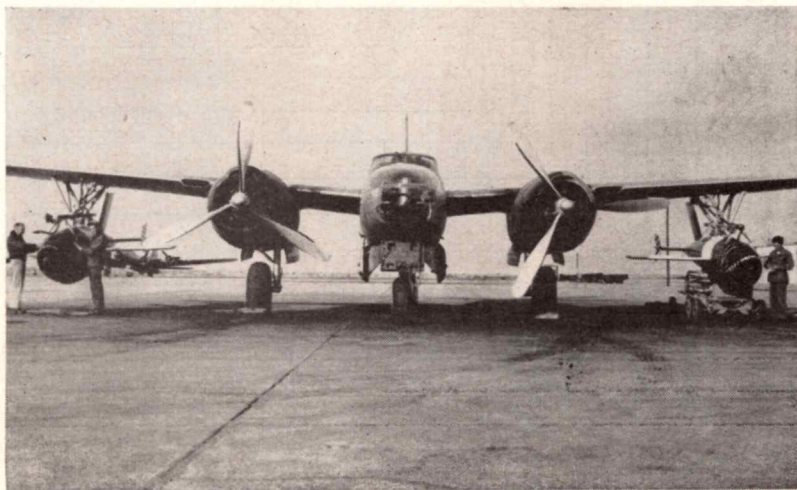
Simplicity of component structure permits easy assembly at firing site



housing the parachutes. The ailerons, elevators and rudder are semi-monocoque construction with magnesium skin on light dural spars and are statically balanced.

The full cantilever horizontal and vertical stabilizers are the same type construction as the wing, with all three panels a single assembly. No ribs are provided in the structure other than at the tips. The vertical fin has a removable tip above the rudder which is attached to the fin by two piano hinges. Construction is magnesium skin on dural spars.

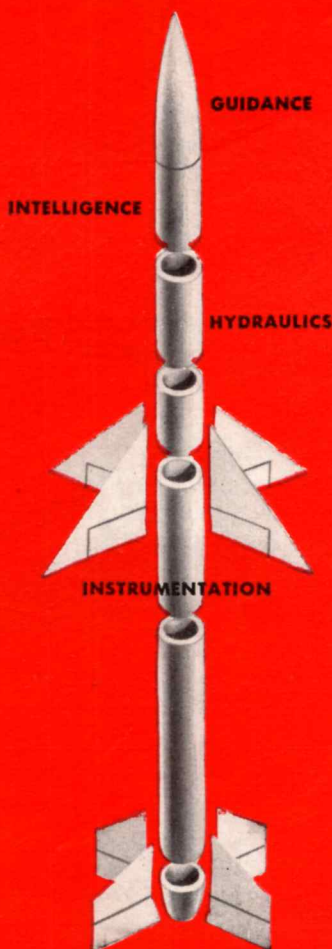
Ryan and Air Force technicians



Douglas B-26 light bomber is mother ship for pair of Ryan Firebee drones

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JULY 1954

THE efforts in solid propellant rocket development are directed to achieve flexibility in design, high performance, reliability, and low cost. In summary, the factors which at present are helping mostly to approach these ideals are as follows:

1. Internal burning charge design. (Combustion chamber case insulated from hot gases.)

2. Casting processes. (Large and small charges made with nearly equal ease. Cost possibly much lower than high pressure molding and extrusion.)

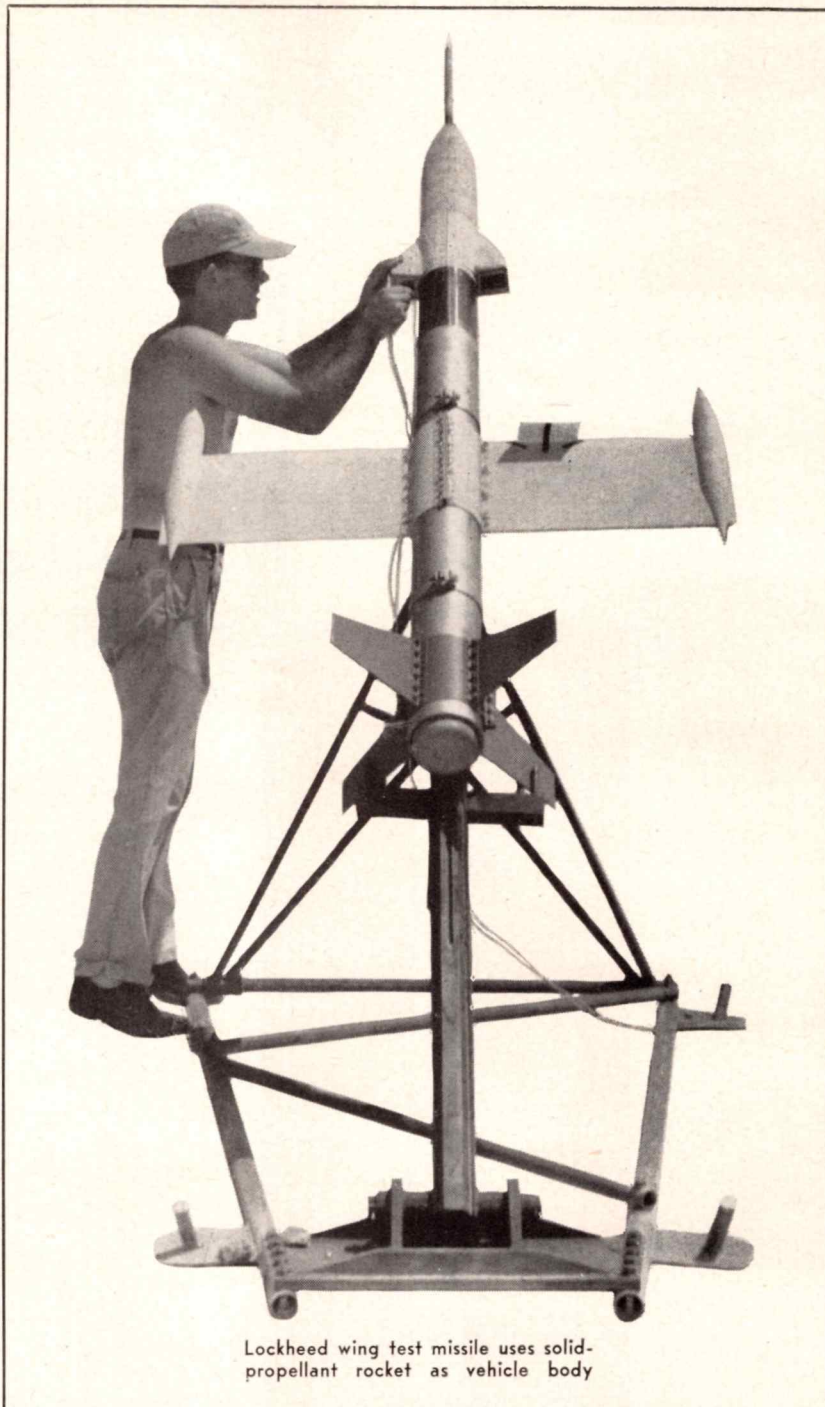
3. High energy, high density propellants. (Energy per unit volume and per unit weight high, results in decreased overall motor weight and, usually, decreased cost.)

4. Motor construction materials of high strength and low weight. Improved fabrication techniques.

5. High strength, low conductivity, heat resistant materials. (Allows low weight for parts exposed to combustion gases, such as the exhaust nozzle.)

6. "Gasless" igniters (negligible ignition pressure peak, provides increased reliability).

The chief advantage of solid propellant rockets, as compared to liquid propellant rockets, is their greater ease of utilization. After preparation, at the point of manufacture, they are easily transported and may usually be fired with simple electrical circuits. Elaborate field servicing equipment is usually not needed. Also because of the simplicity of its design, the solid propellant rocket is cheaper than the liquid rocket for most 1-shot uses. For many applications, solid



Lockheed wing test missile uses solid-propellant rocket as vehicle body



missile propulsion

Simplicity, economy and ease of handling recommend the dry powders for special purposes

SOLID PROPELLANTS

By C. E. BARTLEY

Director, Rocket Division, Grand Central Aircraft Company

propellant rockets are also superior to liquid propellant rockets in total impulse to total weight ratio, primarily because of greater energy available per unit volume. A comparison of some liquid vs. solid properties is given in Table 1.

The rocket unit consists of a charge of solid propellant within a combustion chamber and an exhaust nozzle through which the products of combustion of the solid propellant escape (Fig. 1). The reaction due to the expulsion of the combustion products is the thrust of the rocket. The propellants used in rockets, just as those used in guns, do not explode but burn away at a definite rate on those surfaces which are exposed to the hot gases or flame within the combustion chamber. The rate at which the surface of a propellant recedes in a direction normal to itself during burning is designated as the rate of burning and is usually expressed as in/sec. The burning rate depends upon the chamber pressure, increasing with higher pressures but for many propellants, the burning rates at a chamber pressure of 2000 psi lie between one and two in stroke sec. Now the thrust of a rocket motor may be considered as equal to the product of exhaust velocity and mass flow, so that in order to get a large thrust, a large burning surface must be used to obtain a large mass flow. Similarly, to obtain a long duration thrust only

TABLE I Comparison of Some Liquid and Solid Propellants at 1000 PSIA			
Propellant	Aniline-RFNA	Ethyl Alcohol-LO ₂	Typical Solid Propellant
Specific Impulse (sec)	203	244	200
Density, lb/ft ³	86.5	65.5	110
Impulse/unit vol., (lb) (sec) (Cu) (Ft.)	17,500	16,000	22,000

a small portion of the propellant charge must burn at a time. Since a combustion chamber of a given size will contain only a certain weight of propellant, the thrust may be made large for a short time by providing a large burning surface, or small for a long time by providing a small burning surface.

Broadly speaking, there are two types of solid propellant rockets which are commonly designated as restricted or unrestricted burning rockets, respectively.

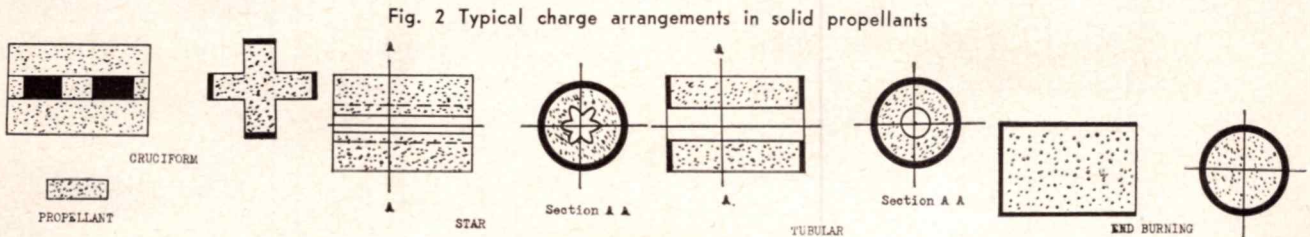
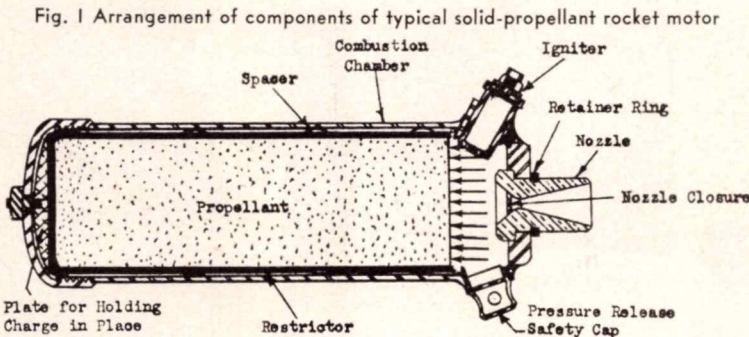
In the restricted burning rockets, the propellant charge is made in the form of a solid right circular cylinder. The cylindrical side surfaces and one end face are inhibited or restricted from burning by a suitable lining or coating, and burning is allowed to proceed from one end only. This type of rocket is sometimes called end burning or cigarette burning. The

duration of thrust obtained from a restricted burning rocket is proportional to the length of the charge and depends upon the chamber pressure and the type of propellant used. The thrust obtained from such a rocket is proportional to the area of the circular burning surface and depends upon the chamber pressure, the type of propellant and the efficacy of the rocket unit design.

In the unrestricted burning rocket the propellant charge is often in the form of a hollow right circular cylinder. This charge is held in place by a suitable grid or trap, but is uninhibited except for the few support points required to mount it. The charge is ignited and allowed to burn on all surfaces with no attempt made to restrict the burning. The thrust from such a unit is proportional to the burning surface and depends upon the chamber pressure, the type of propellant used, and the design of the rocket unit and powder grain. The duration is proportional to the thickness of the cylindrical wall (web thickness) and depends upon the chamber pressure, the type of propellant and the internal geometry of the combustion chamber and powder grain. It should be noted that in the unrestricted burning rocket the combustion gas must flow lengthwise through the unit, parallel to the burning surface of the propellant grain.

The chamber pressure generated by either type of rocket unit is a function of the ratio of the burning surface area to the cross sectional area of the exhaust nozzle throat. For the unrestricted burning rocket the chamber pressure also depends to a marked degree upon the geometry of the propellant charge and the internal geometry of the combustion chamber.

The types of solid propellant rockets described above do not include all types by any means, but are simply two extremes of charge

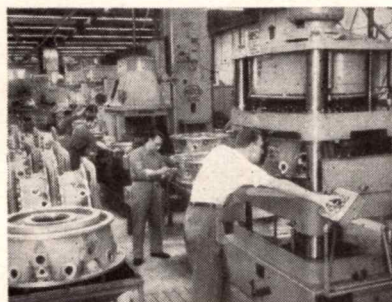


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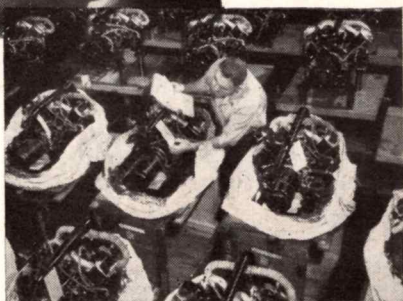
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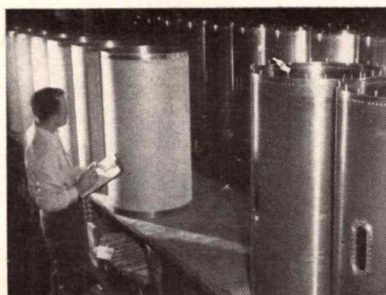
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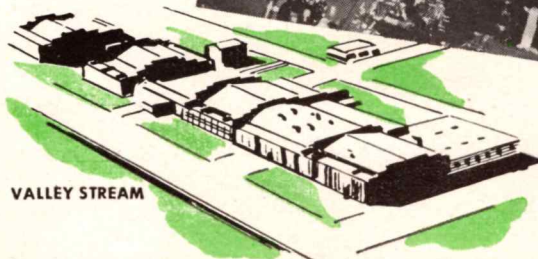
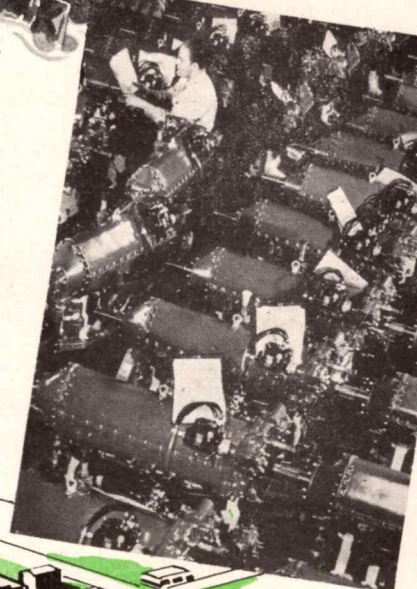
Experimental and production test cells to accommodate quantity output of auxiliary power generators—Fairchild turbojet engines.



1925: Open-air engine test stand. At right: Mass production of in-line inverted air-cooled engines during World War II.



Proficiency in fabrication of sheet metal for Fairchild's J44 turbojet cowlings, combustion chambers and nozzles.



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From these accomplishments and years of experience in engineering design—and in mass production of aircraft engines and powerplants—came the know-how for the development of today's jet engines, auxiliary powerplants, custom made precision built equipment for highly specialized functions and new types of underwater ordnance. Other projects, still "classified", are adding more and more power and strength to our National Defense effort.

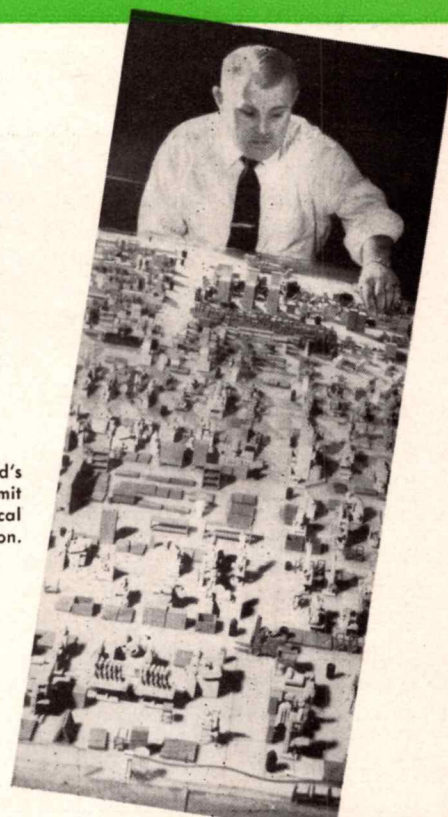


Complete research laboratory provides facilities for testing new theories, new fuels—new metals.

Miniature models of Fairchild's production equipment permit efficient planning for economical production.

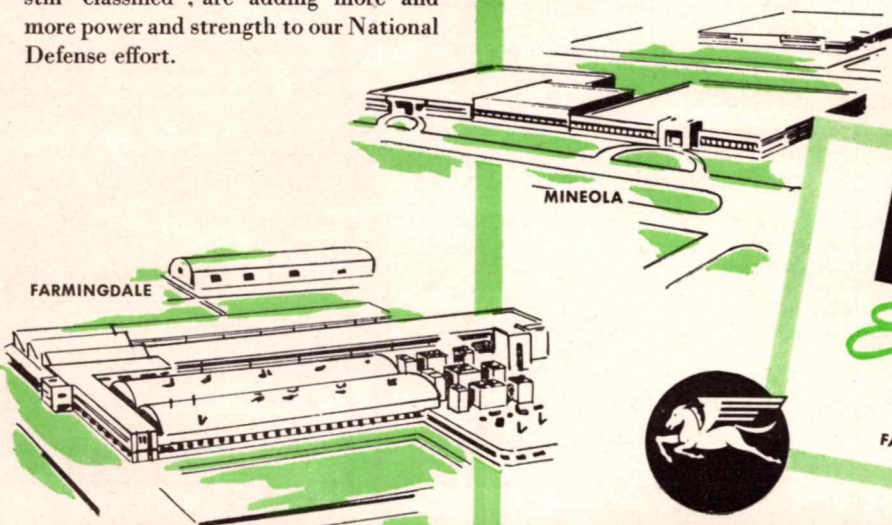
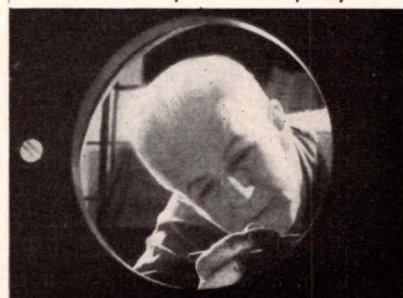
TEAMWORK IN RESEARCH-DESIGN AND MANUFACTURING

Sound, creative engineering at Fairchild springs from experience. Confidence inspires teamwork and stability—provides the urge to experiment into new areas, to test new theories, new metals and new fuels. From the drafting boards come new designs for advanced powerplants and underwater ordnance. In the manufacturing plant itself, experienced production specialists impatiently seek better ways of producing higher quality products at minimum cost. Past performances and present assignments hint of even greater dependence upon Fairchild for the vital components of tomorrow's more complex weapons systems.



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design. Fig. 2 shows a variety of charge arrangements that have been used in rockets.

Generally speaking, unrestricted burning rockets are used where application of thrust is required for periods ranging from 0.05 to 10 sec., and restricted burning rockets are used in applications which require thrust lasting from 4 to 120 sec. The term semi-restricted will be employed to designate propellant arrangements which are neither end burning nor unrestricted.

Practical Developments

The solid propellant rocket, in its essential features, is remarkably simple. However, the development of a practical rocket motor that is reliable, convenient to use, and moderately easy to manufacture has been a lengthy and complex process.

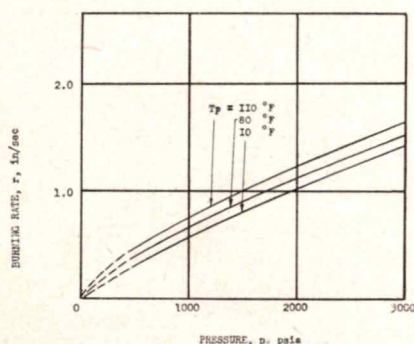


Fig. 3 Effect of temperature on burning rate of solid propellant rocket

ess. Because of the importance of these practical considerations, discussion of solid propellant rockets must necessarily refer to the state of the art.

In Table II is an outline of the general scope of performance and application attained by solid propellant rockets. The rapid development of this field makes it difficult to separate experimental units or propellants from successful utilization, and it also makes a table of this type subject to rapid obsolescence. However, as a rough general survey, it should prove helpful.

The flexibility in design that is both useful and possible is very great. By utilization of suitable designs in various cases it is possible to obtain thrust variations, and burning time variations ranging over a factor of 10^3 . Total impulse, in different designs, can vary by factors of 10^4 . Approximately 14

different applications, and 10 different propellants are listed. Both applications, and propellants represent main lines of effort, and the number of each would increase considerably if all the various modifications and models are taken into account.

It will be noted that the ratio of total impulse to total loaded weight has not varied over such a wide range. This is due to the limitation on the energy per unit mass that can be obtained from solid chemical fuels. Because of this, features of rocket performance, other than specific impulse, receive considerable attention.

There are three characteristics which are peculiar to solid propellant rockets, and which might limit their utilization. These limitations may be briefly designated by the following terms:

- Temperature sensitivity—the variation of performance with propellant charge temperature. An example of the temperature effect upon burning rate is shown by Fig. 3.
- Temperature limits—a rocket unit will malfunction if its temperature, before firing, does not lie between certain limiting temperatures.

- The combustion limit—some propellants do not burn satisfactorily at low pressures.

The cost of solid propellants has been high, at the very best, due to safety requirements necessary in their manufacturing processes and the high basic material cost. The trend is to attempt to use less expensive materials in propellants for some applications, even though relatively low performance results. Because of the infancy of some processes—the cast process a notable example—streamlining of manufacturing has not been perfected. Regardless of the high propellant charge cost (\$1 to \$5 per pound being a reasonable range, depending upon design) the motor construction is so simple that the overall cost of the complete solid propellant rocket unit may be less than a comparable liquid propellant rocket which uses much less expensive propellant materials. Furthermore, the simplicity of operation makes the solid propellant rocket motor particularly desirable for field use. In addition to rocket propulsion, the gas generation capabilities of solid propellants indicate that they may be used for many novel applications in the future.

END

TABLE II
General Characteristics of Two Types
of Solid Propellant Rocket Motors

Type	Unrestricted and Semi-restricted Burning.	Restricted Burning
Thrust	500 to >50,000 lb	100 to 3000 lb
Duration	0.05 to 10 sec	4 to 120 sec
Impulse	30 to >100,000 (lb) (sec)	1000 to >100,000 (lb) (sec)
Propellants commonly employed	Ballistite (extruded); Cordite (British, Russian, German) NDRC moulded composite Thermosetting, cast, composite; British plastic composite.	Cordite, NDRC moulded composite; Asphalt thermoplastic composite; Synthetic rubber thermosetting composite.
Applications	Artillery rockets, armor piercing bombs, anti-aircraft rockets, air to ground rockets, rockets for assisted take-off of light aircraft, glide bombs, suicide aircraft, booster rockets, long range rockets.	Aircraft assisted take-off and superperformance, underwater projectiles, glide bombs, large airborne missiles, booster rockets, gas generation, sounding rockets.
Ratio of total impulse to total loaded weight (exclusive of payload)	50 to greater than 100 sec.	50 to 100 sec
Jet blast	Proportional to thrust, usually severe exhaust flame from ballistite.	Proportional to thrust, long duration units usually have mild exhaust flame to reduce heating of mechanical components.

Most of the composite propellants produce a smoky exhaust jet.



technical
bulletin

new motor for small fans, blowers, pumps

light ★ 23½ ounces

rugged ★ 2000 hours
brush life,
minimum

small ★ 6 inches long,
2¼ inches in diameter

performance data

- ★ 50 watts continuous at 7500 RPM
- ★ 40° centigrade rise at sea level operation and normal ambient
- ★ Weight 23½ ounces
- ★ Dimensions 6 inches long, 2¼ inches diameter
- ★ Brush life at least 2000 hours
- ★ Designed to meet ANM-40 specifications



actual
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This new EEMCO motor was designed for a wide variety of uses where a light, compact unit with unusually long life is required. It is tooled for large quantity, low cost production. All cast components are either die, investment, or molded.

The basic design is extremely flexible. Speed can be varied by changes in winding and/or lamination stack length. Wound for 28 volt D.C.; it can be wound for either 110 volt A.C. or D.C.

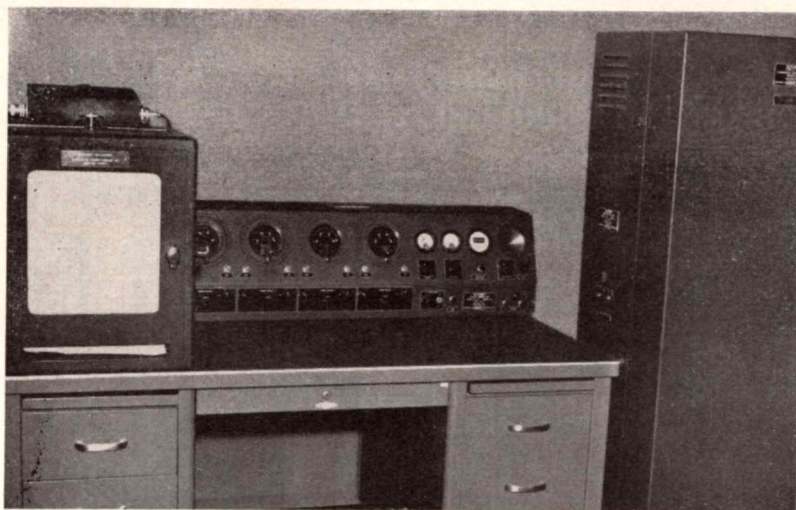
electrical engineering and
manufacturing corporation

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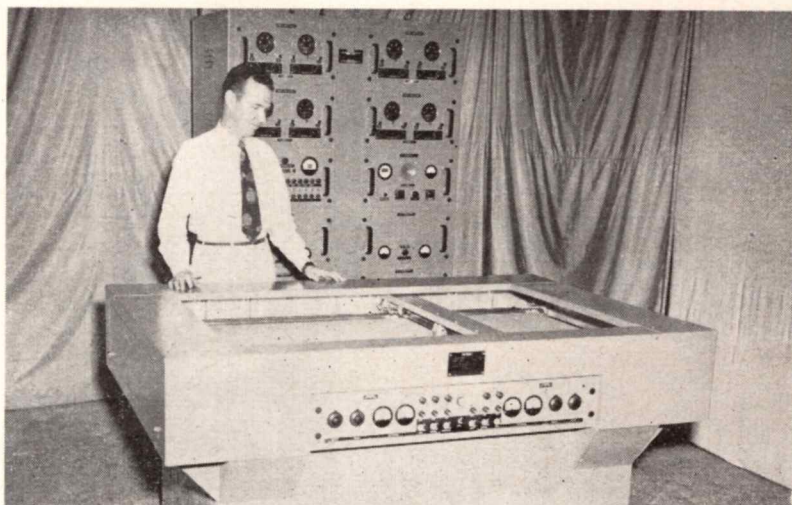
SINCE the very beginning of the present missile tracking and guidance program, there has been a great need for accurately determining the position of missiles in space with respect to time, both for research purposes and for operational use of the missiles.

Continuous-wave, phase-comparison techniques for missile tracking and guidance were used on a limited scale during the early development stage. In the V-2 development, several such techniques were considered, but were abandoned at that time in favor of other methods due to the difficulties of performing phase measurements at radio frequencies. The innovation of the heterodyne phase-comparison technique, which forms the basis for the Raydist continuous-wave systems, simplifies the problem by allowing the phase-comparison measurements to be made at audio-frequencies.

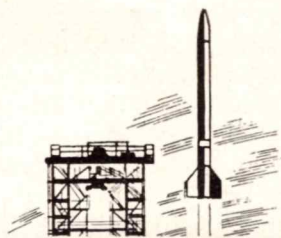
Raydist techniques, using continuous-wave, non-line-of-sight, heterodyne phase-comparison methods (which allow precision in the order of one foot to be obtained for radio location purposes) have expanded the use of Raydist in the missile tracking field. Im-



Console Master Station of Raydist ER system installed at NAOTS Chincoteague, Va. for missile tracking



Raydist automatic plotting board designed and built for Wright-Patterson AFB, Dayton, Ohio



missile electronics

NEW RAYDIST TRACKING SYSTEMS

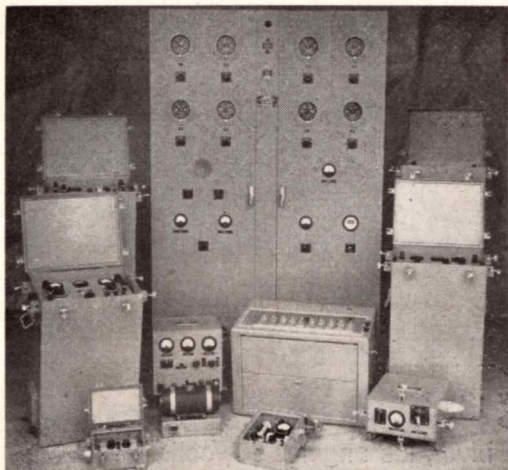
By C. E. HASTINGS

and

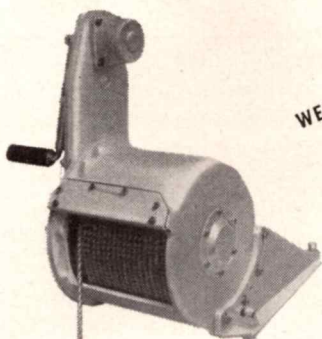
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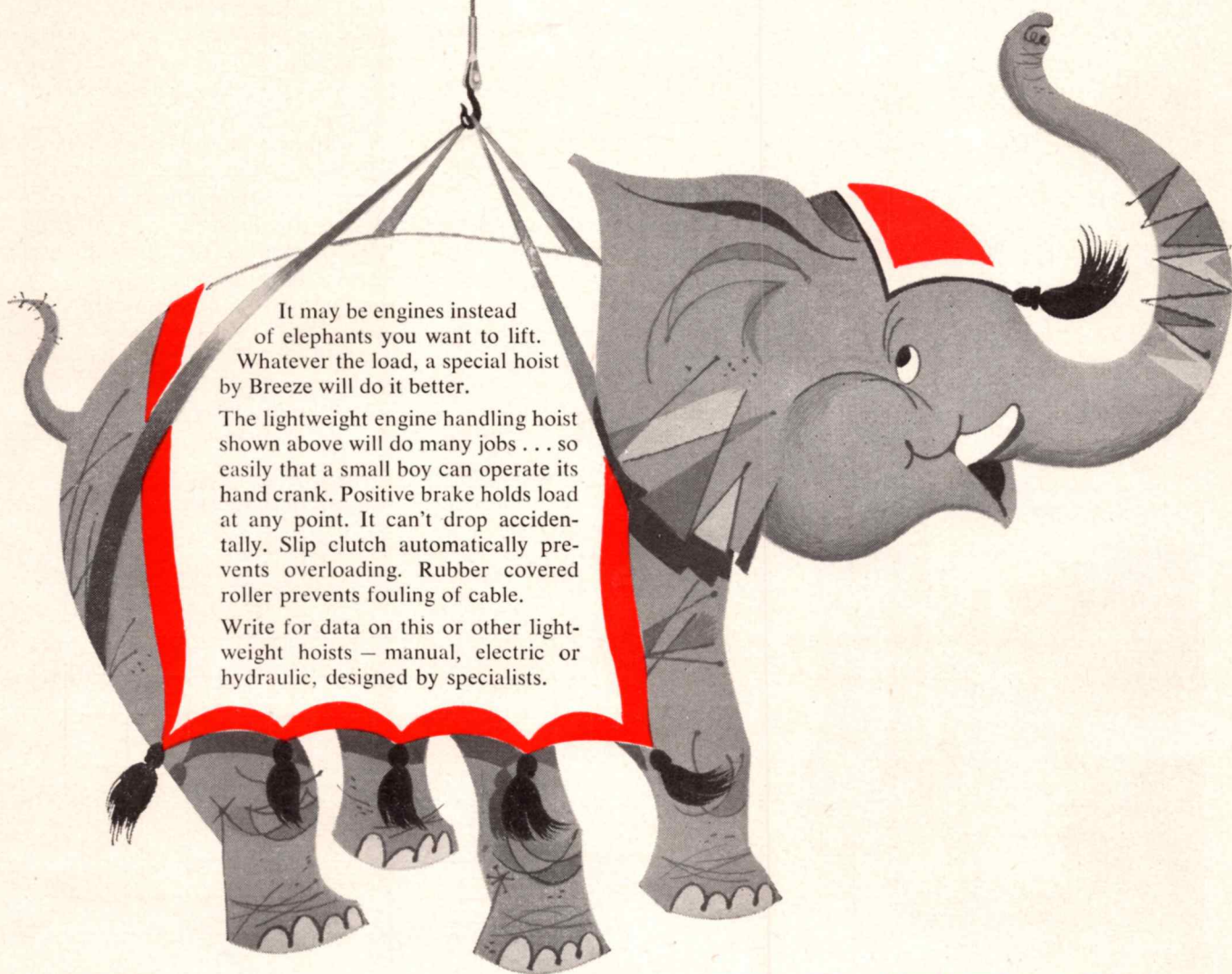
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provement and ability to get good geometrical intersections through large volumes of space and simplification of the reduction and presentation of data have greatly expanded its usefulness for these purposes. Raydist systems have undergone steady development and are now being used in many applications in which operational simplicity and highly accurate determination of position are important.

In addition to the basic problems of missile tracking and guidance, these systems are also finding application in associated problems such as evaluation, training procedure, miss-distance methods and as a safety feature for destroying a missile that is out of control.

The requirements for a missile tracking system vary with the test range conditions and with the types of missiles. One of the factors that is common for all installations is that high sensitivity of measurement and high precision of measurement of position-versus-time are very desirable. If these are achieved, the data can be used to measure or verify velocities and accelerations.

In most applications space is at a premium in the missile. In some missiles no equipment for tracking can be used; in others, a small

radio transmitter can be carried. In the larger missiles a considerable amount of equipment is often carried. In some problems the missile tracking records need only extend to a limited range from the launching point, in other problems it is desirable to track the missile continuously to the point of impact. It is often desirable that a tracking system be flexible enough to allow its use for different missiles and allow the system to cover both short-range and long-range problems.

For any application the surface coverage area and the 3-dimensional volume in which the system will yield data with a prescribed accuracy can be evaluated and set up as a specification for the system to be used. It is also desirable that a tracking system be automatic in operation, as the high accelerations and high velocities obtained make it very difficult for operators to manually operate tracking controls on the older types of tracking systems.

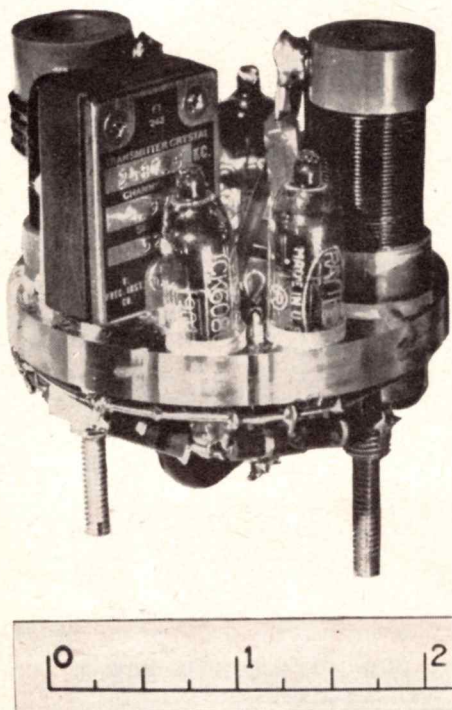
The Raydist systems meet many of the requirements for missile tracking. They yield high accuracy both in line-of-sight operations and in long-range non-line-of-sight tests. They require that a small radio transmitter be carried in the missile, but in many appli-

cations this space can be provided and the advantage of fully automatic tracking from the launching point is realized.

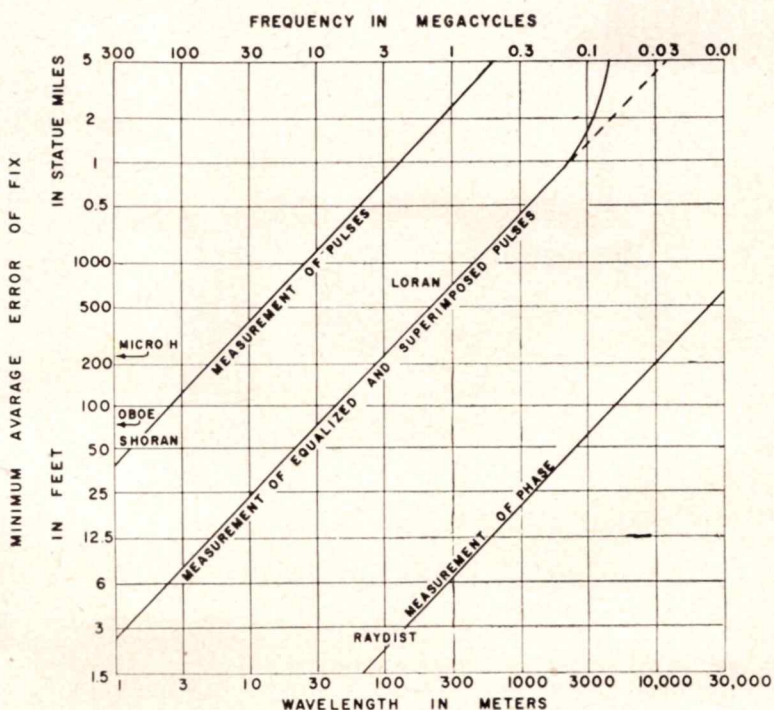
The heterodyne CW technique used in Raydist was first used at Langley Field, Va. in 1940 to determine actual time-distance records of an airplane. The system in a more refined form, including electromechanical phase-comparison meters for surveying applications, was delivered to the Air Force in 1946.

A Raydist system was installed in the Bahama Islands by the Long Range Proving Ground for evaluation purposes in connection with the missile range. The master station for the system was located on Grand Bahama Island and the relay stations were located on three outlying islands. The installation was set up with a Y configuration and the outlying island stations relayed their signals by radio links back to Grand Bahama Island. At the master station, 3-dimensional recording of data concerning the position of an airborne CW transmitter on a radio frequency of approximately 1.7 mc resulted in 3-dimensional data concerning the position of the transmitter. The system had sufficient range with a 100-watt transmitter in the aircraft that an air-

Expendable miniature CW transmitter developed for missile application



Plot of error vs wavelength for various systems reveals unmatched Raydist accuracy



nose for trouble



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plane was actually tracked on the mainland of Florida as it took off from the surface of the airport.

The Naval Aviation Ordnance Station at Chincoteague, in 1953, ordered a 3-dimensional Type ER system of this type which was completed late in January of this year. It was made to operate at the manufacturer's laboratory in Hampton and was recently delivered to Chincoteague where it will soon be installed when the sites are ready.

While this system has advantages in the simplification of the data handling problems and the problems of getting good geometric intersections and sensitivity of this system through wide areas of space, it does have the disadvantage of requiring more apparatus in the missile or aircraft than the hyperbolic Raydist tracking system. But the system delivered is flexible so that if it is not possible to install the increased amount of range equipment in the aircraft or particular missile, the system is capable of tracking in the hyperbolic form with only a small transmitter in the missile.

A portable system for aircraft or missile tracking has been developed. This unit has its master station built into a small panel truck and the relay stations are on the floor to the rear of the vehicle. This is a completely

packaged system and has been used successfully to track high-speed aircraft and sailplanes.

Several small aircraft missile transmitters have been developed suitable for relatively short-range operations or for operations in which relay stations will be available within short ranges of the missile and in the area in which position is to be determined. Extremely rugged units of this kind have been designed and show the applicability of Raydist units to small missiles.

A number of methods have been developed for presenting Raydist data in a convenient workable form. The data is presented directly on phasemeter dials in the form of a coefficient in which one revolution of the large instrument pointer corresponds to one-half cycle of the Raydist frequency. The dial is marked in 100 divisions. With the system operating on a frequency of 1.7 mc, one dial division represents approximately three ft. on the baseline.

Power-driven phasemeters are sometimes used. These can drive servo units which may in turn be used to operate plotting boards, remote indicators or calculating devices. Direct-inking, continuous strip chart recorders are also normally used. On these records each pen completes one sawtooth rec-

ord for each one-half wavelength of the Raydist frequency.

These charts prove useful in analyzing data both during and after completion of a test. The strip chart records can be read at any time and the measurements can then be reduced by IBM technique as is presently being done at Eglin Air Force Base, or on general purpose electronic computers as in the measurements obtained at the Long Range Proving Ground.

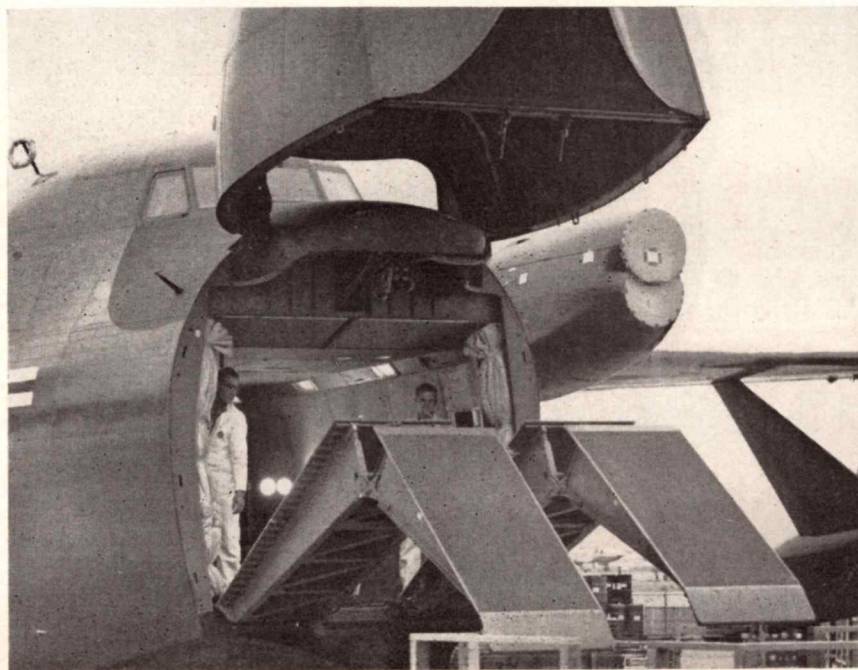
Tracking in 3-dimensions to very high orders of accuracy results in a considerable quantity of data and in complex methods of data handling and reducing regardless of the type of tracking system used. This is true whether the tracking system measures angles, ranges, or difference in distances. Once the programming for the Raydist data has been established it is reportedly less time consuming to reduce Raydist 3-dimensional data than it is to reduce theodolite data. Actually the equations are more convenient for the hyperbolic form of Raydist than for the optical data. Optical data requires more elaborate reading of the original data.

Raydist is particularly applicable to plotting board techniques since the system has been made to operate automatically. The full precision of the system is difficult to handle on a plotting board, since missiles cover wide areas of space very rapidly and precisions to the order of a few feet cannot be automatically plotted except by taking out a small area in the whole system. A Raydist plotting board has been developed which plots the 2-dimensional position of a missile automatically for safety purposes in evaluating the position of the missile and any factors of the danger of the missile to populated areas.

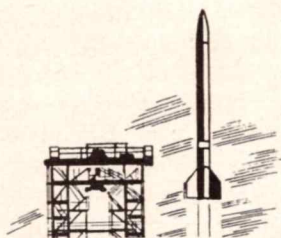
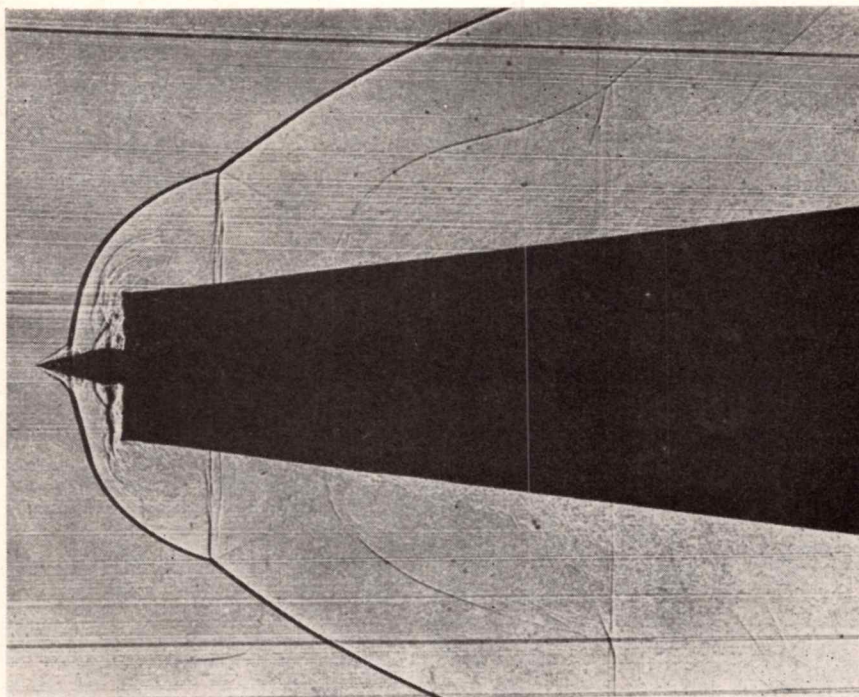
Raydist systems and equipment have demonstrated a wide flexibility in their application to missile tracking and guidance. Improvements during the last few years in the application of Raydist techniques have been very rapid and expansion in the use and diversity of applications of Raydist to this missile field is to be expected.

END

New Convair R3Y-2 Tradewind flying boat features bow doors with hydraulic folding ramp



Bow wave shock pattern
vicinity air inlet of ramjet
engine at supersonic speed



missile design

Supersonic speed regime follows
radically different
principles than familiar subsonic

AERODYNAMIC PRINCIPLES

By E. ARTHUR BONNEY

Dynamic Analysis Group,
JHU Applied Physics Laboratory

DESIGN of a guided missile depends principally on the purpose for which it is employed, although it can never be denied that individual designer's preferences play a big part in this choice.

Missiles have a greater variety of purposes than planes, such as (1) anti-aircraft, (2) ground-to-ground on a long or short-range basis, (3) air-to-ground, or (4) air-to-air, and are generally "one-shot."

For the latter reason, weight in itself does not become such a critical item as it is in the standard airplane. Likewise, for certain of the purposes listed above (all except the long-range ground-to-ground), drag is not a really critical item.

This allows further leeway to simplify the design to allow the most direct type of control, such as

cruciform wing and tail arrangements, and all-movable wings or control surfaces. Removing the requirement for banking the missile to produce maneuvers in any plane is an enormous simplification in control system design and provides for increased response time without complications due to dynamic results of rapid roll motion of the body.

These considerations lead generally to completely symmetrical arrangements of aerodynamic surfaces on the body, with the location of the control and main lifting surfaces still dependent on purpose and design whim at the moment.

The Canard arrangement uses small control surfaces mounted forward to increase the angle of at-

tack of the entire body, and large aft fixed wing surface to produce the required maneuverability.

The so-called "wing-control" design is actually also a Canard type except that the control surface is mounted nearer the center of gravity of the overall configuration and provides the main lift of the design, the tail surfaces providing the necessary aerodynamic stability and control characteristics.

The "tail-control" design acts like the Canard in that a control surface is used to increase the angle of attack of the body and wing to provide the necessary lift, but in this case the control surface is placed at the rear.

The above three types are most generally considered for the design of guided missiles and each has cer-

tain aerodynamic advantages over the other. To go into all of the relative good and bad points would violate national security. A few obvious points can be reviewed.

The Canard and tail-control arrangements have the advantage of small control surfaces while the wing-control allows for the production of the required lift entirely without benefit of angle of attack if so desired. Actual aerodynamic angles of attack of the control surface are minimized with the tail control design, since the surface deflects in the opposite direction to that of the body; however, the control force is in the opposite direction to that of the final maneuver force.

Flow conditions about aerodynamic bodies and planar surfaces are considerably different at supersonic speeds than at subsonic. These differences have a marked impact on the resulting design.

For example, in subsonic flow, the air ahead of the wing is warned of the oncoming surface by the pressure impulses which are created by its motion, and the air spreads to go around the surface before it actually arrives. In speeding up to go around the surface, a negative pressure is created by the air. Hence, subsonic surfaces are cambered on the upper portion to increase the speed of air on this side, providing as much negative or lift-producing pressure on the top of the surface as possible. Approximately 70 per cent of the lift of a good subsonic wing is produced on the upper side.

A supersonic lifting surface, on

the other hand, by traveling at speeds faster than the speed of the pressure impulses, produces no warning of its impending arrival and the air literally piles up in front of it (and must be pushed aside) producing a shock wave by its presence.

Whether the pressure on a surface is positive or negative relative to the free stream depends only on the relative angle between any point on the surface and the free stream flow direction. If the relative direction is such as to force the air to turn away from the body, that is, tends to push the streamlines together, a shock wave will be created and the pressure and density will be increased.

If on the other hand, the wall along which the flow is passing turns in a direction away from the airstream, an expansion wave will be created and the pressure and density will be decreased. An illustration of oblique shock and expansion waves is shown in Fig. 1.

Because of the above characteristics noted for the supersonic case, it becomes most practical to design the airfoils with symmetrical cross-sectional shapes such as double wedges or double circular arc. There is nothing to be gained by cambering the wing.

But in the case of the usual subsonic airfoils, the lift vector is inclined ahead of the normal to the chordline, that of the usual symmetrical supersonic airfoil shapes as well as that of symmetrical bodies of revolution lies along the normal to the chordline or centerline itself. This makes the estima-

tion of induced or lift-drag considerably more simple than in the subsonic case when the lift (or normal force) characteristics are known.

The existence of the shock wave due to the piling up of air ahead of surfaces in a supersonic stream adds another term to the usual drag terms of the subsonic case. This is referred to as wave or pressure drag. In general, the wave drag may be expected to amount to approximately 50 per cent of the total zero-lift (wave plus skin-friction) drag of a guided missile design.

The lift-curve coefficient slopes and wave drag coefficients tend to decrease with Mach number approximately as $\sqrt{M^2 - 1}$. Inasmuch as total forces are calculated as the coefficient times certain scale factors and pressure and the square of the Mach number, this means that, at high Mach numbers, the total drag or lift curve slope will vary almost directly as the Mach number. This is in contrast to the condition at subsonic speeds wherein these parameters vary as the square of the Mach number or velocity.

In the transonic speed range where the wave drag is first beginning to be felt, a very rapid drag rise is experienced just before Mach 1 is reached, and a peak in the drag coefficient curve occurs somewhere in the vicinity of $M = 1$ depending upon the design of the configuration; and the coefficient curve then falls off as indicated above with further increase in Mach number. This leads to a

Fig. 1 Shock wave pattern on double-wedge airfoil at supersonic speed

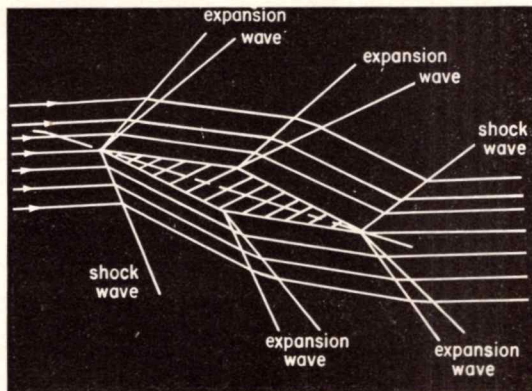
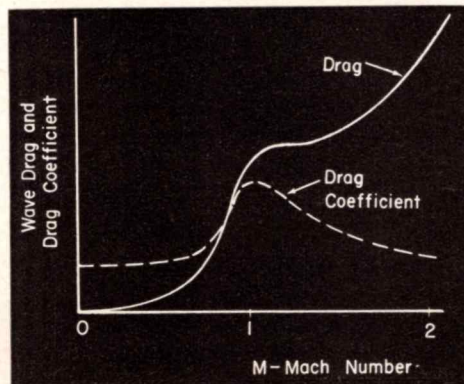


Fig. 2 Variation of total drag and drag coefficient with airplane Mach number



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drag coefficient and total drag curve variations with Mach number as shown in Fig. 2.

The interesting shape of the wave-drag curve has one other consequence on design, namely the smaller percentage of increased thrust required to increase speed from, say, M 1.2 to 2.0 as compared with that to increase from M 0.4 to 1.2. This is, of course, an important matter in reaching very high supersonic speeds.

The aerodynamic differences between subsonic and supersonic flow discussed above lead to very marked differences in the optimum design of the individual components of a guided missile or supersonic airplane as compared with its subsonic counterpart. For example, due to the importance of minimizing the piling up of air ahead of either a body of revolution or aerodynamic lifting surface, these components are generally best designed with sharp points or leading edges. Actually the nose of a body of revolution of fixed length-to-diameter ratio designed for least drag will have a slightly rounded nose; this is due to the reduction in angle of the nose as its diameter and, hence projected area, become larger and the relative unimportance of the small blunt portion of high pressure, but low projected frontal area.

A nose shape using an ogival or arc-shaped contour rather than conical shape will actually have less drag than that of the cor-

responding cone for this reason.

Likewise, wing surfaces are built with sharp leading and trailing edges in designs for use in the current Mach number range. A double-wedge shape will have the least wave drag for a given thickness ratio, however the double-circular-arc or "biconvex" cross-sectional shape has been shown to have the least drag for a given strength. Thickness ratios of three to eight percent are normal with supersonic surfaces whereas values much higher than this are used in subsonic practice. The biconvex shape has the added advantage of a complete absence of sharp corners as exist with the double wedge shapes, thus having less tendency to produce separation of flow and rapid changes in hinge moments at large angles of attack.

In cases where solid or liquid rockets are used for propulsion, the exit of the nozzle is quite often smaller than the outside diameter of the body. In such a case, the wave drag of the total configuration can be reduced by the addition of a "boattail." This has sometimes been termed as the "opposite of a nose," being a tapered portion at the base wherein the diameter is decreasing toward the rear. A large negative pressure will exist at the base of a missile flying at supersonic speeds and the pressure over the boattail will not be as great negatively as that of the corresponding area of the base that was removed and hence the prod-

uct of the pressure times area which produces drag in that region will be reduced.

The question is often asked "In consideration of its effect on design of guided missiles, is supersonic flow simply an extension of subsonic flow or is it a new field in itself and all subsonic concepts should be forgotten when using it?" As in most questions of this type, there is no single answer. For example, local pressure distributions are markedly different in the two regimes, and yet a positive deflection of a surface still produces an up load. Hubs must be located at different chordwise locations to minimize hinge moments and yet the principles of stable and unstable hinge moments still apply. Likewise the principles of stability and control are unchanged in supersonic flight.

Downwash (deflection of air passing over a forward surface and hence striking an aft surface at an angle different from that had the forward surface not been present) continues to exist at supersonic speeds and has the same effect on stability and control characteristics as at subsonic speeds. As noted above, the variations of forces and moments with Mach number is different in the two ranges leading to differences in trim conditions (ratio of angle of attack to control surface deflection) at different Mach numbers in the supersonic speed range whereas these trim conditions were essentially constant with Mach number in the truly subsonic range.

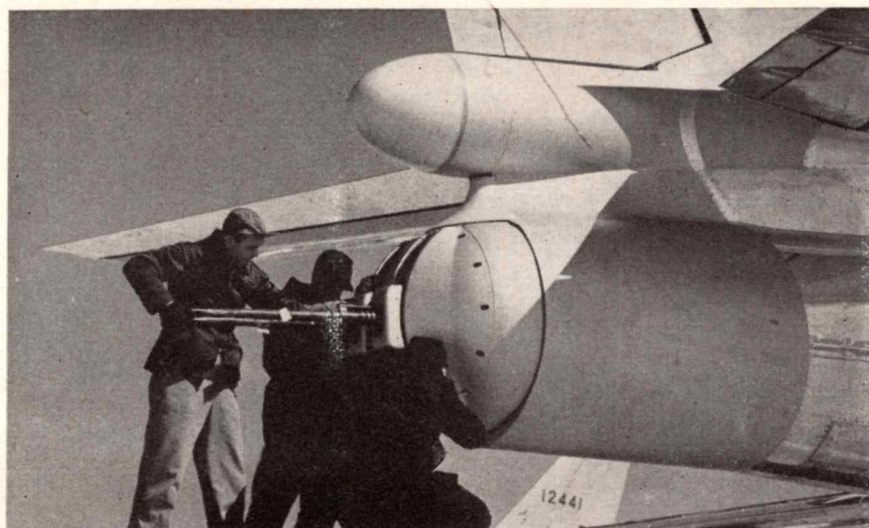
Of very considerable consequence and importance is the effect of the above mentioned variations of aerodynamic characteristics on resulting aeroelastic forces. These forces are dependent on the

aerodynamic "q", i.e. $\frac{\rho V^2}{2}$ or $\alpha \rho M^2$, and also on the relative

trim conditions of the particular design. Hence any aerodynamic effect on trim may well accentuate or relieve the aeroelastic problems. A given design must be checked at all extremes of trim and "q" to cover the possibilities of the presence of this problem.

END

First detail closeup of Boeing B-47 medium bomber remote tail turret shows General Electric radar-directed, automatically-fired installation



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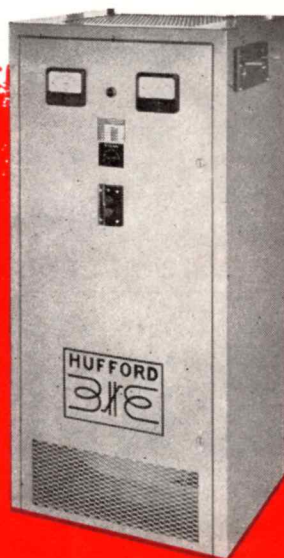
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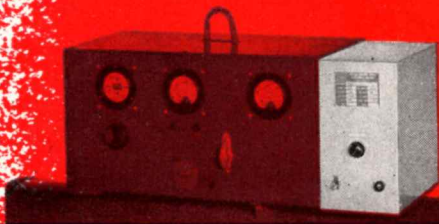


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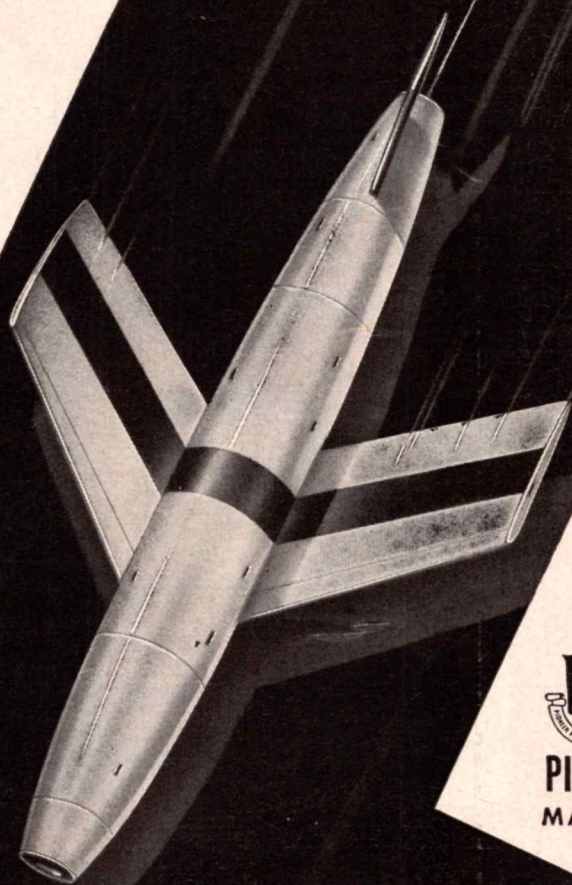
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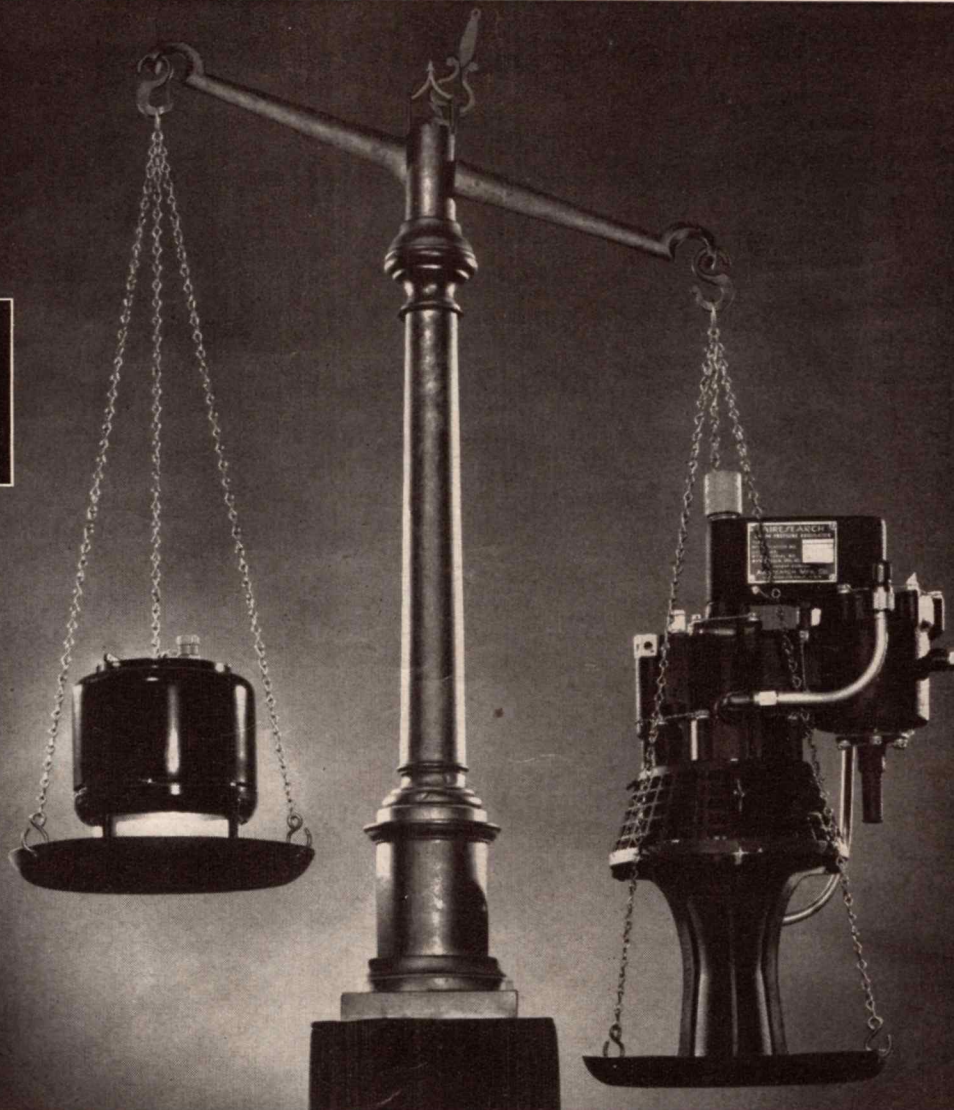
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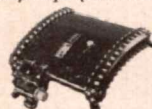
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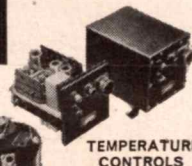
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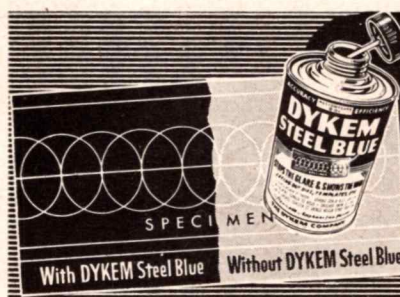
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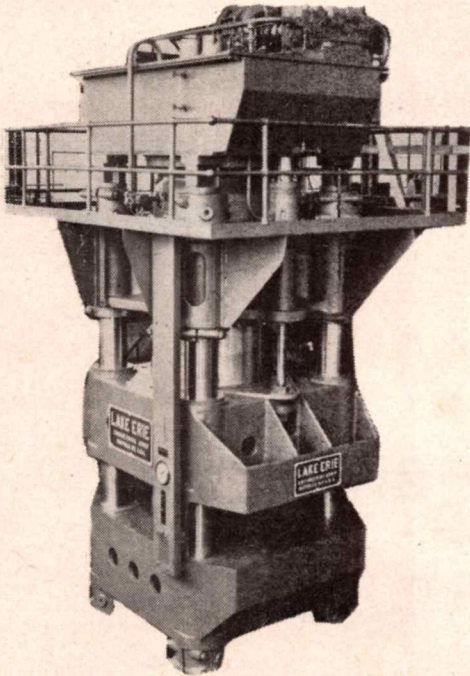
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Write for Bulletin

AARON MACHINERY CO., INC.

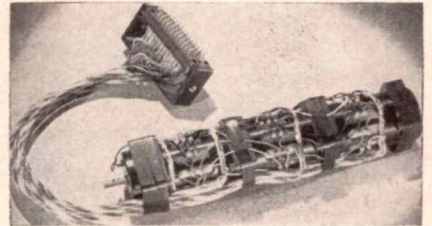
45 Crosby St.

WORTH 4-8244

New York 12, N. Y.

pound system formerly used, (2) There is no interstage cooling problem, (3) The system efficiency is about 1/3 greater, (4) There are no interconnected compressor crankcases for oil return, (5) Less horsepower is required, and (6) The system has positive-pressure rather than high-vacuum suction lines. Chambers available with the new refrigeration system range from small-size units having but a few cubic feet of work space to giant 400 to 500 cu. ft. room-size models.

Tenney Engineering, Inc., Union, N. J.



Digital Converter

Converts variable mechanical positions into unambiguous electrical contact settings. Each standard decade unit has ten possible positions, hence a stack of three decades covers a number range from 000 to 999.

Input is the rotary position of mechanical elements, such as lead screws in measuring devices, etc.; servo motors in remote position indicators, measuring instruments, etc.

Output is discrete electrical contact positions, suitable for operating electric typewriters, for feeding information automatically to digital calculators, or for specific digital display for either visual or photographic reference.

Standard gearing links the brushes of each decade, one to another, to maintain approximate inter-stage relationship while an electromagnetic system provides both the intelligence and actuating force to effect precise contact selections, thus ensuring correct positioning of the brushes relative to the commutator contacts.

The standard model illustrated is limited to about 250 number changes per second in either direction. With special adapter speeds up to 1600 number changes per second are permissible. Speed limitations are mechanical in nature; however, excessive speed itself would not produce errors because the device is not dependent upon counting or accumulating pulses.

Genisco Incorporated, 2233 Federal Ave., Los Angeles, Calif. **END**

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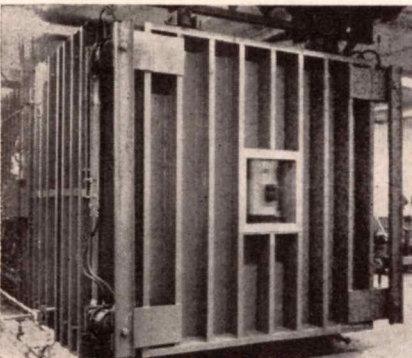
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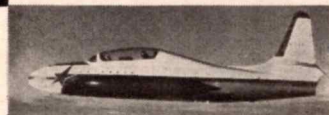
Stratosphere Chamber

The recent adaptation of the cascade system of refrigeration to the Tenney Engineering line of low-temperature stratosphere chambers reduces chamber first cost, results in lower operating costs, enables installation in a smaller area, and provides a simpler refrigeration system.

Contributing to these advantages are the facts that: (1) The cascade system requires but 1/3 the compressor displacement capacity as did the com-



FX-104



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These new development projects offer engineers outstanding opportunity for achievement and promotion. To engineers who seek that opportunity, Lockheed offers:

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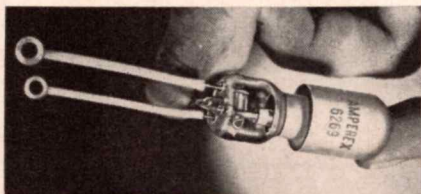
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cause of its miniature size the WW10J has wire lead terminals two in. long. (2½ in. length available.) Wire leads can be furnished for Types WW3J, WW4J, WW8J and WW11J in lengths of 2½ in., 3 in. and 4 in. Both lug and lead terminals are designed to eliminate any strain on the winding, and are made of corrosion resistant metals.

International Resistance Company, 401 N. Broad St., Philadelphia, Pa.

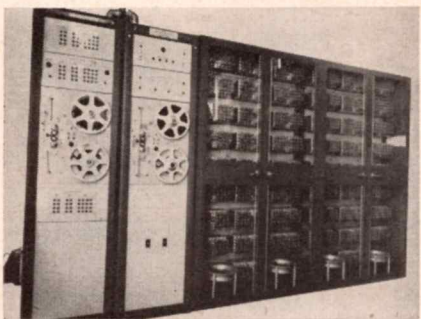


Diode Tube

This tube is an external anode clipper diode and rectifier tube which is only two inches long and ¾ in. in diameter. A miniaturized and ruggedized version of the 3B29, the new 6339 operates under more stringent conditions than its prototype. It is designed to be enclosed in a complete liquid cooled package including power supply and pulse modulator components.

Although developed primarily for radar applications, this tube shows interesting possibilities for use in high voltage circuitry where space requirements are critical.

Amperex Electronic Corporation, 230 Duffy Ave., Hicksville, N. Y.



Pressure Recorder

A system capable of storing and coding (for punch card analysis) data produced simultaneously by 100 pressure-sensing devices has been developed by Potter Instrument Co. Each of the 100 pressure devices is sampled

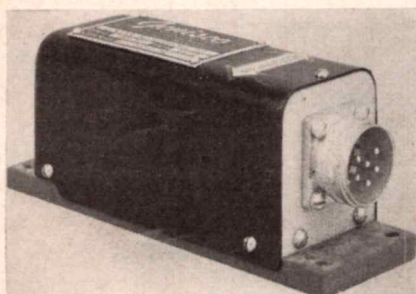
simultaneously several times a minute, and exact four-digit numbers corresponding to the pressure at each point are recorded sequentially on magnetic tape. The readings are later played back into punch-card equipment for analysis.

One hundred separate pressure-sensitive switches are used. These switches are designed to open an electrical circuit when the pressures on both sides are equal. A pressure to be measured is applied to one side of a switch. The second side of each switch is connected to a common pressure line.

At the beginning of a measuring cycle, the pressure in the common tank is at some value known to be lower than any of the pressures being measured. As the cycle begins, a compressor raises the pressure in the tank in linear fashion.

At the same time pulses from a 1,000-cps oscillator are gated onto one contact of all 100 pressure-sensitive switches. Initially, since the pressure applied on the common pressure line is lower than any of the pressures applied on the measuring side, the switch contacts are closed, and 1,000-cps pulses are fed into each of 100 four-digit electronic counters.

Potter Instrument Co., Inc., 115 Cutter Mill Rd., Great Neck, N. Y.



Accelerometer

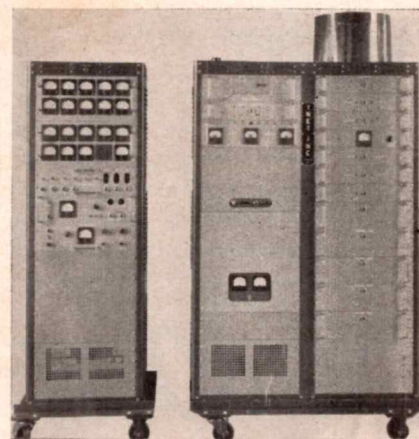
The Model GMH Accelerometer combines the advantages of light weight and small sizes with constant output characteristics over wide temperature ranges. The instrument is basically a Model GMO Accelerometer with an insulated, heated jacket to maintain a relatively constant thermal environment within the instrument.

The Model GMH is available in ranges from ±1 G to ±30 G with natural frequencies higher than usual for potentiometer-type instruments. The pickoff element is a precision linear potentiometer whose resistance

winding and brush are made of platinum alloys to assure low noise and long life. Movement of the seismic mass in all directions except the sensitive axis, which is perpendicular to the mounting base, is substantially restrained.

The unit is silicone-oil damped, with internal construction providing shear damping which is partially temperature compensated. As the instrument is hermetically sealed, it operates reliably under any atmospheric condition.

Genisco Incorporated, 2233 Federal Ave., Los Angeles, Calif.



Control Unit

A control unit and a power unit from one of Inet's recent projects are shown above. The machines are part of a missile station used in guided missile pre-flight tests. They provide all flight control conditions prior to take-off.

The +400, +300, +150, +25, -25, and -375 v. supplies are electronically regulated. They all make use of the output of -600 v. regulator as a reference voltage, thus eliminating the need for separate reference tubes and insuring that independent drift in the regulators cannot occur. The 6 v. supply employs a magnetic amplifier regulator, as does the 28 v. supply.

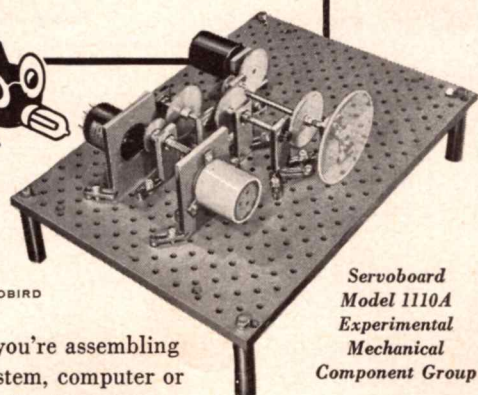
Testpoints, which can be reached from the front of the unit, are provided, insuring uncomplicated test procedures. The components in both units are assembled in drawers and can easily be interchanged with spares. Both units are housed in BUD cabinets, which were specified by the customer.

Inet Div. of Leach Industries, Inc., 4441 S. Santa Fe Ave., Los Angeles, Calif.

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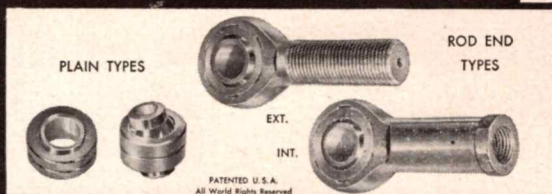
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Thousands in use. Backed by years of service life. Wide variety of Plain Types in bore sizes 3/16" to 6" Dia. Rod end types in similar size range with externally or internally threaded shanks. Our Engineers welcome an opportunity of studying individual requirements and prescribing a type or types which will serve under your demanding conditions. Southwest can design special types to fit individual specifications. As a result of thorough study of different operating conditions, various steel alloys have been used to meet specific needs. Write for revised Engineering Manual describing complete line. Address Dept. AD-54.

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Precision
Unlimited



The breeding of Fine Pitch Instrument Gears involves both science and artisanship. Requires craftsmen—not just machinists.

Why? Because these little animals have complex personalities—sometimes hard to deal with.

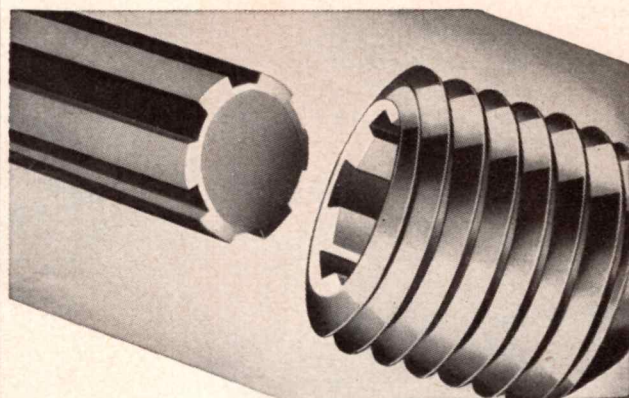
Now, here we have done nothing else, day after day for some 20 years.

The point is: if you need Fine Pitch Gears—GET THEM HERE.

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CHELSEA, MICHIGAN, Box 328

Phones: Detroit WO. 5-2399—Chelsea: GREENWOOD 9-1791

6829



Hold Tight with Bristol's exclusive multiple-spline

• These flush-fitting set screws can be set tighter, easier, faster—wherever design considerations dictate. The added holding power of the multiple-spline lets you use fewer and smaller screws with no loss of strength. Withstand severe shock and vibration. Sizes: 0 wire to 1/2 in. diameter. Get them from your industrial distributor. Write for free bulletins showing applications.

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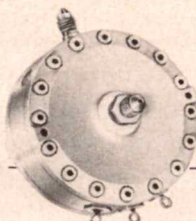
BRISTOL'S SOCKET SCREWS
Hex and Multiple-Spline
Socket Screws, Cap and Set

THE BRISTOL COMPANY, Socket Screw Division, Waterbury 20, Conn.



Giannini HIGH PRESSURE TRANSMITTERS

Giannini high pressure transmitters accurately translate pressure into proportional electrical signals of relatively high power, and require little or no amplification.



MODEL 46129

These high pressure transmitters incorporate a unique direct coupling arrangement between bourdon tube and potentiometer element which obtains movement amplification without the use of gearing or linkage, thus giving high sensitivity, repeatability, and low hysteresis.

Ranges from 0-100 psi. to 0-6500 psi., (abs., diff., gage). Instruments are available for operation under either normal or extreme conditions of vibration and acceleration or for corrosive media.

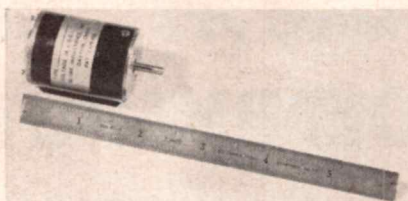
Other models also available for low pressure and high altitude applications. Write for complete engineering information.



MODEL 46139

G. M. GIANNINI & CO., INC.
AIRBORNE INSTRUMENT DIVISION
PASADENA 1, CALIFORNIA

Giannini

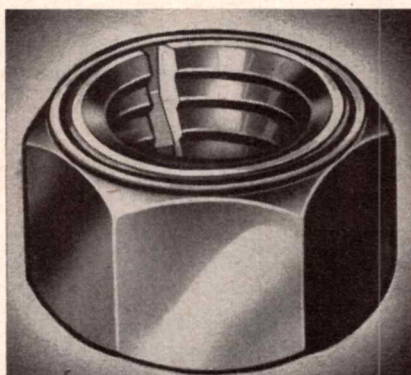


Miniature Motor

A new variation of the basic Globe Moto-Mite is now available in production quantities. This new unit allows complete environmental protection in the same 1.75 in. length previously required for the open motor. Utilizing a metallic end bell and a very close fitting cover, the unit will withstand severe humidity and salt spray requirements while still maintaining the 13/16 in. diameter. The shaft is available in either 1/8 or 3/16 in. dia. and either solder or threaded terminals may be specified. The larger shaft allows an integral pinion to be cut directly on the shaft as illustrated.

For power requirements in excess of that available from the short frame (mm) motor the long frame (1l) motor is available in 2 3/32 in. length at slightly longer delivery. Radio noise shielding is not as complete in either version as it is in the enclosed shielded standard motor but is satisfactory especially where auxiliary shielding may be provided in the application.

Globe Industries, Inc., 1784 Stanley Ave., Dayton 4, Ohio.



High Temperature Fasteners

Basically, a high temperature fastener requires a reliable locking feature, the ability to remove the fastener after exposure to temperatures and a bolt tension of known and relatively constant value.

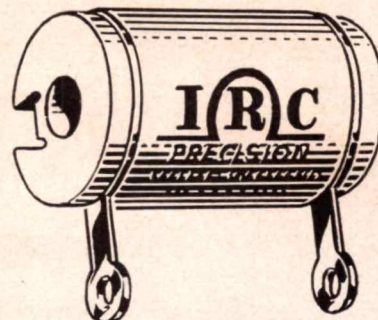
Removal of nuts at lower temperatures is not a severe problem. But when the fastener has been exposed to temperatures up to 1200 deg. F., or even up to 1600 deg. F., it is a differ-

ent story. Welding may have occurred. The bolt threads are oxidized and may even have grown. The Dura-Loc provides for clearance between the nut and bolt thread during removal. Result is safe, easy removal with no damage to either threads. To prevent welding between nut and bolt threads, all Dura-Loc nuts have plated or special finishes.

Dura-Loc gives bolt tensions with less than 15 percent variation at a given wrench torque.

Normal manufacturing variations in the taper of the Dura-Loc collet do not affect bolt tension and locking force as they do with predeformed pitch diameter types. The tolerance of the bolt threads doesn't bother the Dura-Loc either. Relatively constant locking torque and bolt tension are obtained on all tolerance bolts.

The Delron Company, Inc., 5224 Southern Ave., South Gate, Calif.



Resistors

All IRC resistors except WW8J and WW10J are wound with double or multiple section windings. This is in accordance with RETMA and MIL-R-93-A specifications. The direction of the winding is reversed in adjoining sections and each section is balanced to have approximately the same number of turns. This type of non-inductive winding minimizes the inductance and provides a winding that has little coupling effect with other parts of the circuit.

IRC windings are multiple-vacuum impregnated with a unique material that remains at approximately the same consistency through the entire temperature range to which the resistors may be subjected. This material is neither glassy hard nor tacky soft under any condition so that wire strains are minimized. A higher degree of stability and freedom from noise is achieved together with excellent humidity protection.

All IRC Precision types have lug terminals, except Type WW10J. Be-

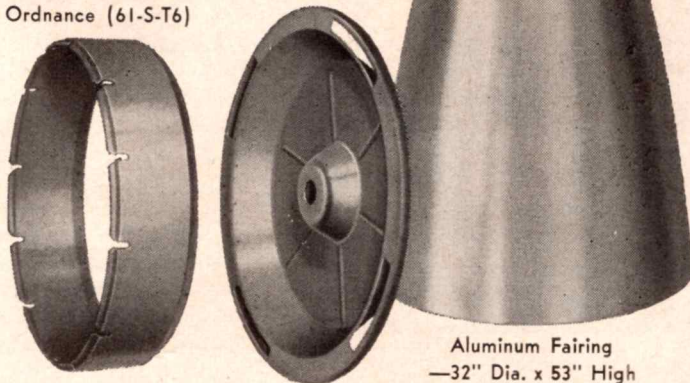
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YOUR part may be as small as a thimble—or require a blank up to 180 inches in diameter. Whatever the requirement, PHOENIXSPUN craftsmen can produce close-tolerance spinings from steel, stainless steel, aluminum, monel, copper, and other metals. More than twelve years of dependable service to leading industries in widely diversified fields.

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VELBESTOS 170-1

CONFORMS TO
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AMS 3232F
AN-G-171
MIL-G-7021
33-P-22C

THE VELLUMOID COMPANY • WORCESTER 6 • MASS.

ularly adaptable for use in the aircraft and missile industries, although the concept is simple and capable of wide application.

The pressure transmitter was designed to provide long life, a high degree of reliability and precision performance in the severe vibrational, temperature and corrosive environment normal to operation in aircraft and missiles. Linear output is not dependent on the bellows spring rate but is substantially controlled by a temperature-compensated spring. A novel bellows suspension system minimizes response to acceleration and vibration. The basic Model GPT is designed as an absolute pressure instrument although similar models are easily adaptable to gage or differential applications. The unit can be supplied with either one or two potentiometers.

Genisco Incorporated, 2233 Federal

Ave., Los Angeles 64, Calif.



Hydraulic Test

This Greer Model 10SE3V-20V test stand is widely used throughout the missile field for general laboratory use in testing the performance of missile components such as servo valves, actuating cylinders, accumulators, hose

lines, pumps, etc., operating at pressures up to 3400 psi and flow capacities up to 20 gpm.

Infinitely variable pressure regulation from 500 to 3000 psi is provided by a sequence-relief valve and a manually controlled variable pressure relay valve. Infinitely variable volume control up to 20 gpm is provided by means of an external hand wheel control. A foot pump circuit provides high pressure static and leakage tests.

The pressure manifold is divided into a number of sub-circuits, each controlled by a shut-off valve leading to outlet valves and connections. This arrangement provides a 3000 psi circuit, a 5000 psi circuit, a 300 psi circuit, and a 1000 psi circuit which can be used simultaneously. Each sub-circuit has a relief valve and pressure gauge.

Greer Hydraulics, Inc., 454 18th St., Brooklyn, N. Y.

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for progress in
**ELECTRONIC
WIRING!**

**For High Dielectric
Strength, specify—**

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—90° to +250°C

For an extra margin of dependability at maximum operating temperatures, specify these rugged Teflon insulated hook-up wires. Available in stranded sizes from 20 to 30 AWG with shields and teflon jackets or lacquered braids. Constructed to meet highest government and commercial standards, Tensolon Wires feature the new Tensulated-Teflon covering that eliminates pin holes and other imperfections.

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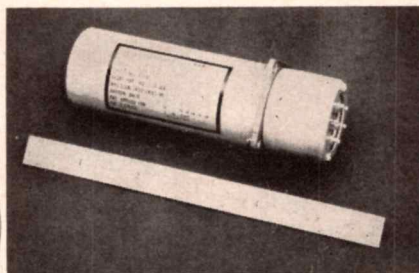
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cathode or filament is properly heated. Delay periods of 2 seconds to 300 seconds are available. Fully compensated between range of -60 deg. to +85 deg. C. Heater voltages up to 117 volts are available and contacts (SPST—normally open or closed) carry 6 amperes maximum.

Thomas A. Edison, Inc., Instrument Div., West Orange, N.J.



Motor Switch

The Globe motor switch is a combination of the "Moto-Mite" motor, governor controlled, if required, a small concentric gear reduction and a single pole double throw switch mechanism.

The motor switch will interrupt an inductive high current load to introduce a jizzle or activating signal in a control circuit, or any other circuit where high speed S.P.D.T. switching action is desired.



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Up to 60% Silver Brazing
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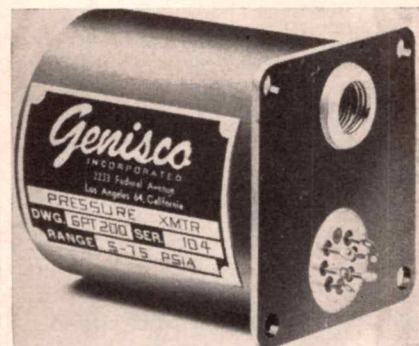
- ★ Produced from standard wire stocks. No lead time needed for dies or exact strip.
- ★ Suitable for use with induction, gas-air, furnace, or any of the commonly used heating methods.
- ★ Available in EASY FLO and SILFOS as well as Copper, Bronze and other alloys.
- ★ Diameters up to 4" I.D., wire thicknesses from .010 upward.



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Pressure Transducer

The Genisco Pressure Transducer, Model GPT, is basically a precision linear potentiometer driven by a pressure responsive bellows. The instrument incorporates a number of unique design features which make it particularly tungsten contacts, wiping action on contacts and positive make and break of contacts. All switch and motor connections are located at the top on the terminal block at the convenience of installations.

Globe Industries, Inc., 1784 Stanley Ave., Dayton 4, Ohio.

\$5,000 in Awards

Monthly awards will be made at the time the winning designs appear in the August, September, October, November and December, 1954, editions of AERO DIGEST.

Monthly Awards:

- First: \$250. (\$1250 for five months.)
- Second: 125. (625 for five months.)
- Third: 100. (500 for five months.)

Annual Awards:

- First: \$1000
- Second: 750
- Third: 500
- Three honorable mentions, \$125. each — \$375.

Annual Awards will be made concurrent with the announcement of the winners in the February issue, 1955.

In case of ties, duplicate prizes will be awarded.

How to enter your design

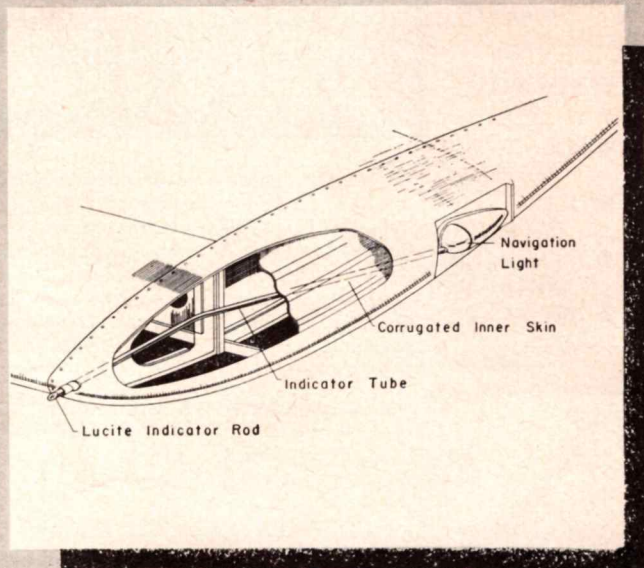
Simply submit your design to The Editor, AERO DIGEST Design Forum, 511 11th Street, N.W., Washington 4, D.C. No entry blank is required, but your entry should be accompanied by a letter stating that the material in your presentation is your original work.

There are no limitations on the length of text used to describe the entry. However, it should contain the following data:

- (a) Name of design
(Example: Throttle Ratchet Mechanism, Rotor Blade Attaching Means, etc.)
- (b) Purpose of design
(Example: To keep throttle in preselected position and to permit motion to full idle cut-off position; To transmit blade loads to fuselage structure while simultaneously permitting flapping and lagging action and control of blade angle, etc.)
- (c) Contest claim
(Example: Reduces complexity by avoiding necessity for long runs of cable; Improves flight safety by permitting pilot to lock unit completely out of system in emergency; Reduces manufacturing cost by using cheaper raw stock and permitting attachment by rivets, rather than bolts, etc.)
- (d) Comment
Where designs involve operating mechanisms, a brief statement of its sequence of operation; where design is part of a system, a brief statement of its function within that system for clarity; or a brief comment on a particularly interesting history of a design in which a previous design proved faulty and why and the manner in which the new design cured the trouble. A statement as to the current use of the design in a specific aircraft and a report of its suitability is always of interest.

(SEE SAMPLE ENTRY)

Here's how to submit your entries:



DESIGN TITLE: PILOT'S NAVIGATION LIGHT INDICATOR

PURPOSE OF DESIGN: To provide indication to pilot that navigation lights are functioning properly.

CONTEST CLAIM: Reduces complexity by obviating need for long run of cable to cockpit and cockpit indicator.

COMMENT: The wingtip navigation lights are not directly visible to the pilot and copilot. A Lucite rod is extended from the surface of the light cover to a position at the wing leading edge. This utilization of the principle of "edge lighting" provides a glow on the forward end of the rod readily visible to the pilot and copilot.

Send all entries to:

AERO DIGEST

design
forum

511 ELEVENTH STREET N.W., WASHINGTON 4, D.C.

**\$5,000
awards
in the
AERO DIGEST**

design
forum

With the August issue, AERO DIGEST begins a Design Forum for engineers in aeronautics in the United States. Cash prizes will be awarded monthly thereafter until the end of the year, when grand awards will be made. A schedule of these awards and when they will be made accompanies this announcement. Purpose of the Forum is to give industry-wide recognition to the research, design, engineering and production achievements of today and to encourage and foster even more brilliant achievements in this industry's great future.

How you can qualify

Any citizen of the United States who is not a staff member or relative of a staff member of AERO DIGEST is eligible to submit an entry in the AERO DIGEST Design Forum.

Rules and suggestions

Entries will be judged on the degree to which they improve flight safety, reduce airplane complexity, or provide a manufacturing cost saving through engineering judgment and the application of technical skill.

Entries can vary from a simple bracket to a complete airplane, power-plant or missile design; there are no limitations on the form or substance of the design.

All entries will be accepted without any restrictions. You do NOT have to be a subscriber to AERO DIGEST nor fill out a complicated official entry blank. It will enhance your entry's clarity and attractiveness if it is neatly drawn in perspective in India ink on double-weight white paper, but all entries will receive equal consideration regardless of degree of artistic effort.

AERO DIGEST requires of entries *first magazine publication rights only*. The magazine specifically renounces any and all other claims to designs submitted. That a design has previously been published in a technical paper or a manual does not disqualify it. Previous publication in an aviation trade journal, however, does disqualify it. *All entrants retain in full any and all other patents, copyrights, or publication rights to their design.*

Each monthly forum competition closes on the first of the month preceding the month of issue and awards. For example, closing date on the awards to be announced in the August issue is July 1. All entries received after the monthly closing date will automatically be considered in judging entries the following month. *All entries, regardless of when received or of whether they win a monthly award, will qualify for the annual grand prizes if mailed on or before December 1, 1954.*

Every effort will be made to take care of all material submitted, but AERO DIGEST cannot be held responsible if material is lost. Receipt of your entry will be promptly acknowledged. To keep the staff work load to a minimum, we request that you ask for the return of your entry only if it has genuinely future value to you. Entries should be clearly marked if you want them returned.

Checks will go to monthly winners as far in advance of publication of the magazine as possible. Annual awards will be made at the time of publication of the February, 1955, issue of AERO DIGEST.

Judging will be done by a distinguished board of aeronautical engineers, the Consulting Editors of AERO DIGEST, under the chairmanship of Robert McLarren:

ROBERT McLARREN, Editor, AERO DIGEST

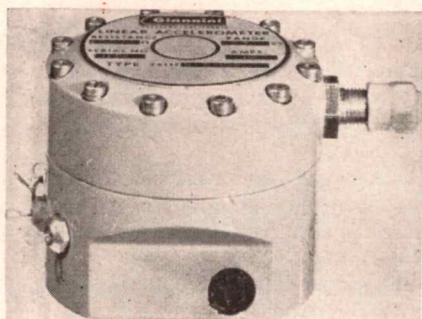
DR. MAX MUNK, Chairman of the Department of Aeronautical Engineering, Catholic University
R. J. SANDSTROM, Vice-President, Engineering, Bell Aircraft Corporation

A. A. VOLLMECKE, Chief, Airframe and Equipment Engineering Branch, Civil Aeronautics Administration

The decision of the judges shall be final.

of safe temperatures—is essential in miniaturized equipment. This makes it a “natural” for the field of guided missiles.

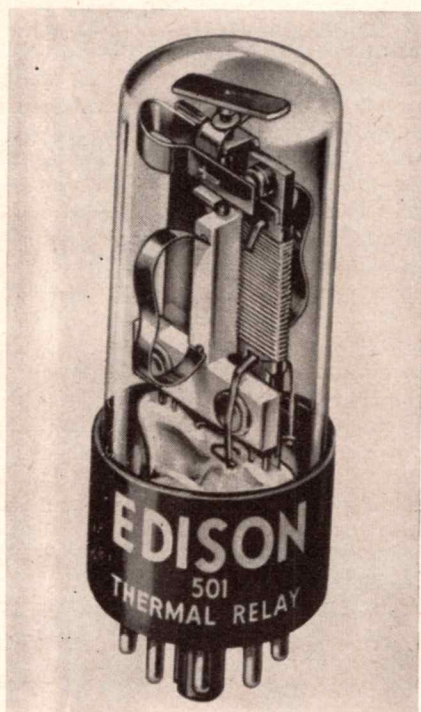
Sanders Associates, Inc., 137 Canal St., Nashua, N. H.



Accelerometer

Giannini Model 24117 linear accelerometer is a lightweight, oil-filled, pressurized unit which is not affected by altitude or atmospheric conditions. It is an extremely long life unit and can be used in installations requiring a compact instrument for acceleration measurements.

G. M. Giannini & Co., Inc., 918 E. Green St., Pasadena, Calif.



Time Delay Relay

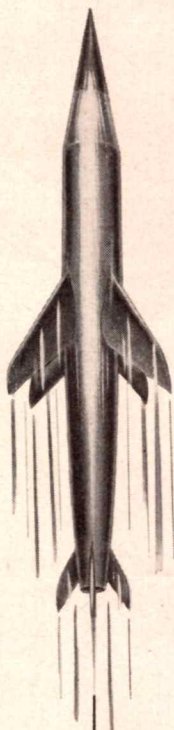
This relay is primarily intended for protection of cathodes in power tubes where it serves to delay the application of voltage to the plate before the

GORN

aircraft controls

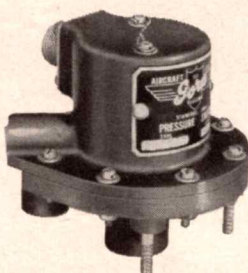
play an important part in research and development of guided missiles.

These are typical examples of the engineering design and development built into all Gorn products.



Differential Pressure Switch

GP-16000 Series. Differential pressure switch of metallic diaphragm construction which senses low differential pressure. Instrument can satisfactorily operate from -65° to 200° F. 3 to 5 amperes current rating inductive and resistive loads. The proof pressure is 7 psi and the burst pressure is 14 psi with a pressure differential of 4" of water. The range and differential can easily be adjusted. Fluid media are oils, fuels and gases. Over-all length $3\frac{3}{4}$ " and $3\frac{1}{2}$ " maximum diameter. All environmental tests are per Mil-E-5272A specification.



Printed Circuit Connector

Available with 6, 8, 10, 12, 15, 18 or 22 contacts. Melamine molded shell with beryllium copper contacts assure excellent conductivity.

Plating—gold over silver prevents corrosion.

Range—.061 to .071 card thickness. Wire size #16. Weep holes for condensation removal.



Pressure Switch

GP-8000 Series. Pressure-actuated switch of metallic diaphragm construction, completely sealed to prevent leakage, capable of satisfactory operation at temperatures ranging from -65° to 180° F. at sea level to an altitude of 60,000 feet. Adjustable pressures of this series range from $2\frac{1}{2}$ psi to 350 psi with burst pressure of 700 psi. 5 to 10 amperes current rating inductive and resistive loads. All switches are tested and qualified in accordance with Mil-E-5272A for all aircraft environmental conditions. The over-all length including receptacle is 3.3 inches and 2.5 inches in diameter. All switches and components are in compliance with Army, Navy, or Air Force standards.

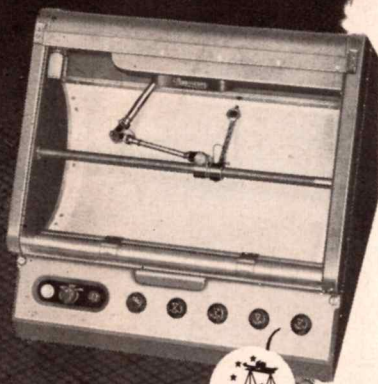


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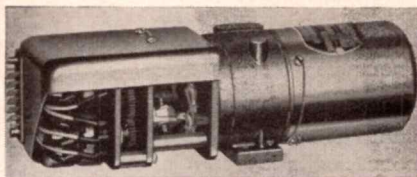
1607 FLOWER ST., GLENDALE, CALIF.

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company, primarily to satisfy the critical demands of computer and military applications.

All features of the company's plastic case diodes have been preserved in the new hermetically-sealed units, which are the result of several years of research and development. As in the past, the platinum-rhuthenium whisker is welded to the germanium pellet.

General Electric Co., Electronics Park, Syracuse, N. Y.



Program Motor

This program motor assembly drives four potentiometers for circuit sequencing in a missile just prior to launching. Assembly includes a 90 v. dc permanent magnet motor with gear train, slip clutch, and limit switches. Size: 2 in. x 2 in. x 7 in. Weight: approximately 1.8 lb. Unit takes two seconds to perform its function in the missile launching and is typical of the many devices custom-designed by Barber-Colman Company for specific application requirements.

Barber-Colman Company, Rockford, Ill.



Subminiature Blower

The Sanders Associates "Minicube" is a complete motor and blower in a 1 in. cube. It is designed for ruggedness, is compact, operates at high velocity (22,000 rpm with a rated life of over 1,000 hrs) and puts out 3 cu. ft. of air/minute. Finds application wherever cooling—maintenance

FLIGHT INSTRUMENTATION by **RAHM**

potentiometer type transducers
for use at temperatures between -60°C. and $+160^{\circ}\text{C.}$

Designs available permit single or multiple range linear output from non-linear input function, and operation over wide ranges of environmental conditions.

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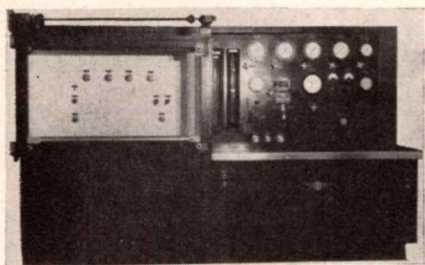
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RAHM INSTRUMENTS, INC.

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5000 enclosure whose size is 5½ in. by 3¾ in. by 3 in.

Automatic Electric Sales Corp., 1033 W. Van Buren St., Chicago, Ill.

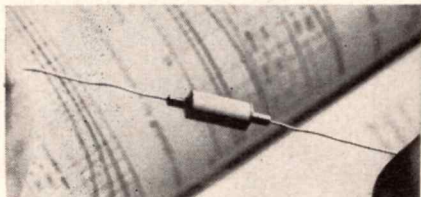


Pneumatic Test

This Greer Model CVA-1-PNEU test stand has been designed to test components employed in missile and aircraft pneumatic systems up to 6000 psi pressure and 3 SCFM flows. The unit is equipped with all dynamic pressure equipment to test these components under simulated flight conditions, in accordance with current practices. Included with this test stand are: a four-stage tandem compressor, air-filtering equipment, and chemical and mechanical dryers. Drying is obtained down to minus 65 deg. F. dewpoint under continuous service.

The test chamber has an electrically driven, armor-plate door which encloses the test chamber during test operations. Control of this door is interlocked with the pressure circuit to prevent opening when an item being tested is under pressure. Two-inch thick bullet-proof windows, front and side, afford visual contact of the component during test.

Greer Hydraulics, Inc., 454 18th St., Brooklyn, N. Y.



Germanium Diodes

The General Electric Company has announced hermetically-sealed ceramic germanium diodes, at no increase in prices. Three JAN types (1N69, 1N70 and 1N81), and some commercial computer types are now available in production quantities. Other commercial types will be available in a few months, at which time most G-E diodes will be hermetically sealed.

The move to hermetically seal all its germanium diodes was made by the

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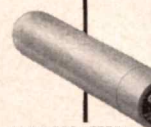
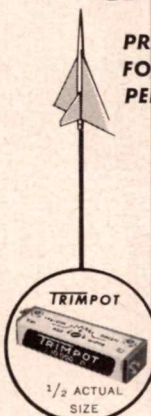
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PERFORMANCE

Bourns instruments feature the finest design and workmanship in wire-wound potentiometry. Their precise electrical signals, requiring no amplification, are used in control systems, telemetering networks and recording circuits. Rugged construction guarantees accurate and dependable performance during the severe shock, vibration and acceleration conditions encountered in aircraft and industrial applications.

Physical variables such as linear displacement, acceleration and pressure are measured to an accuracy of 0.25% of instrument range. Single or dual potentiometers and linear or functional outputs are a few of the many characteristics that can be provided. Besides the hundreds of standard models and ranges available, special designs may be developed for individual requirements.

Bourns **TRIMPOTS** — the ultimate in sub-miniaturization — are used for circuit trimming in miniaturized assemblies subjected to extreme environmental conditions.

Bourns many years of experience in specialized potentiometer instrumentation, plus modern production facilities, assure you of the highest quality instruments attainable.

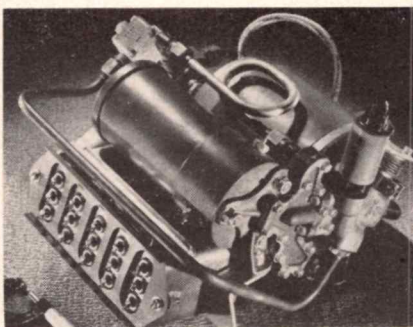


**Bourns
LABORATORIES**
6135 Magnolia Avenue
Riverside, California

Technical Bulletins on Request, Dept. 31
© B. L. PATENTS PENDING

testing crystals, oscillators and other components from temperature variations. Now in use in control for Nike rocket.

Thomas A. Edison, Inc., Instrument Div., West Orange, N.J.



Power Package

Rocket-propelled power packages built by AiResearch Manufacturing Company provide a lightweight source of electrical and hydraulic power for guided missiles. This 17-pound unit replaces bulky, more expensive storage batteries or compressed air bottles. It accepts hot gases from a separate power unit, converting this energy into shaft power for turning an induction generator and a hydraulic pump.

Hot gases from the fuel source strike a turbine wheel, which turns up to 60,000 rpm. A gear box reduces the 60,000 rpm wheel speed to 12,000 rpm shaft power. A generator coupled directly to the gear box converts shaft power to 115-volt, 400-cycle electrical energy. Coupled directly behind the generator is a pump that converts shaft power into hydraulic power. This supplies 2.75 gallons of oil per minute at 1500 psi.

AiResearch Manufacturing Company, 9851 Sepulveda Blvd., Los Angeles, Calif.

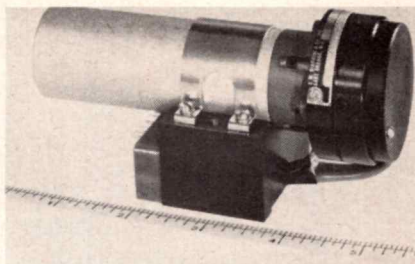


Missile Connector

This is a Cannon Electric Missile Connector Type GMDA Plug. A sled-and-skid type for rack launching with lateral mounting brackets, the GMDA types are equipped with wither

straight, angle 60 deg. or angle 90 deg. end bells. Contact arrangements range from 33 to 50 contacts, accommodating No. 14, No. 10 contacts, and in one arrangement also 2 coaxials for RG 58/U cable. This is an example of the special spring-loaded contact design.

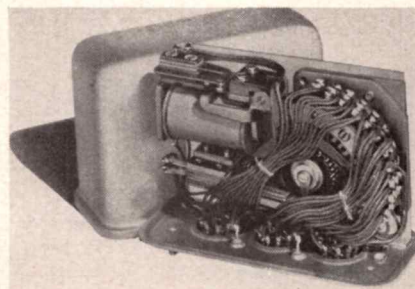
Cannon Electric Co., 3209 Humboldt St., Los Angeles, Calif.



Commutator

G. M. Giannini and Co. announces a motor driven telemetering Commutator that is able to sample 3600 contacts per second and is available in make-before-break or break-before-make, plus various circuit arrangements.

G. M. Giannini & Co., Inc., 918 E. Green St., Pasadena, Calif.



Stepping Switch

Automatic Electric's Type 44 Stepping Switch is hermetically sealed in an atmosphere of dry nitrogen. This switch is highly resistant to shock and vibration, and provides the extra dependability vital to many military and industrial applications. The Type 44 Switch has a top speed of 85 steps per second and can be supplied with ten points (plus "home") in one two or three levels—or with twenty or thirty points (plus "home") in one level. It is available for any voltage from 6 to 110 dc. The Type 44 Stepping Switch with 3 levels can be sealed in the AE 600 Enclosure whose size is 3 5/32 in. by 4 11/16 in. by 2 3/16 in. This switch with 4- to 6-levels can also be sealed in the AE

Lear-Romec submerged fuel booster pump Model RG-11250. Military type B-26 configuration.



Evaluate

the new LEAR-ROMECC submerged fuel booster pump

WHAT IT DOES: Supplies a solid line of vapor-free fuel, thus eliminating vapor lock and permitting the engine-driven fuel pump to function normally for faster starting of engine and faster rate of climb, even with fuel boiling in tank surrounding the booster pump. Also prevents boiling in fuel lines.

HOW IT PERFORMS: Test reports demonstrate that the Lear-Romec Model RG-11250 pump performs satisfactorily up to and including 25,000 feet. Configuration meets specification MIL-P-5249 (USAF). Other Lear-Romec fuel booster pumps available with tested performance up to 50,000 feet.

PRESSURE vs. FLOW CURVE: Unique design of Lear-Romec impeller used in this pump provides a good, flat curve. A maximum of 9 to 10 psi is maintained under conditions of minimum fuel consumption of the engine; 7 to 8 psi at 100 gph; 3 to 4 psi at 200 gph. Can be modified to supply 50 gph at 11 psi — rating of military type B-26 pump.

SPECIAL DESIGN FEATURES: Uses two ball bearings in place of the usual one bearing, to permit safe dry running if the pump is inadvertently allowed to run on an empty tank. Vertically mounted and totally submerged in the bottom of the fuel tank, with only electric leads

and plumbing connections exposed. Excellent "pump-down" characteristics, since the inlet is lower with respect to the mounting flange than other similar pumps. Will pump down to a fuel level of $\frac{1}{4}$ " above the mounting flange. Weight—only 2.7 lbs. Current consumption—2 to 2.4 amperes.

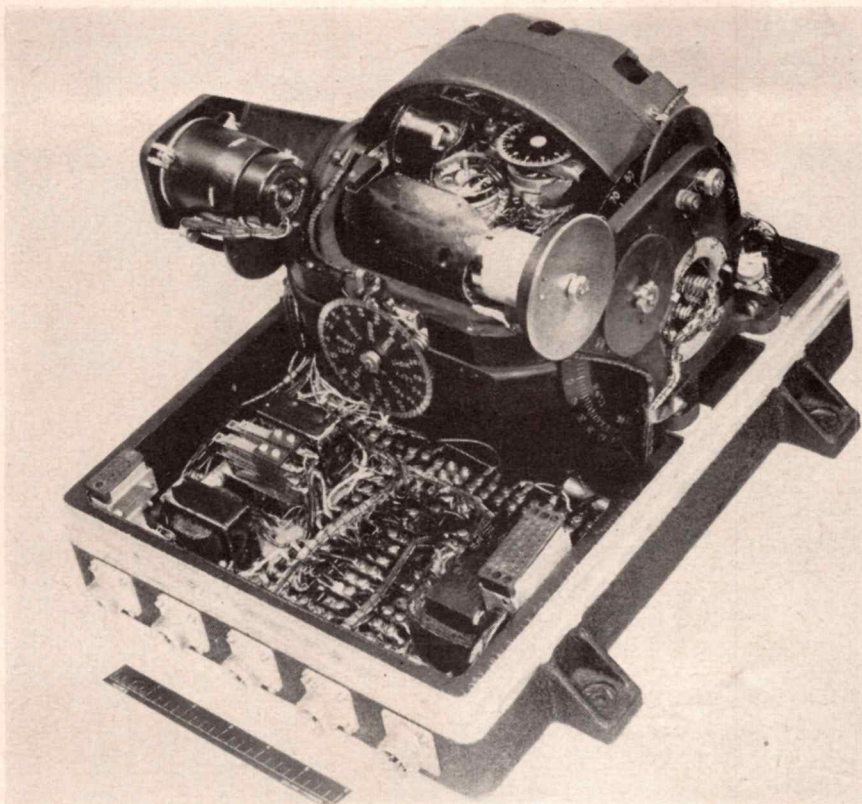
MOST SUITABLE APPLICATIONS: Ideal for helicopters, liaison, small cargo, trainers, and small commercial planes. Also highly suitable for jet engine operated drones and missiles.

WHEN AVAILABLE: Lear-Romec is producing these pumps now and has ample capacity to build them in quantity. Early delivery assured.

QUALITY: Lear-Romec engineering, research, manufacturing procedures, and test facilities represent your assurance that the Model RG-11250 centrifugal fuel booster pump is the finest B-26 type available today. Full engineering and test reports available upon request.

LEAR INC.  **LEAR-ROMECC DIVISION**
Elyria, Ohio
EXECUTIVE OFFICES: LOS ANGELES 34, CALIFORNIA

RO-5



Stable Platform

In combating the hue and cry of gadgetry and complexity being added to the modern airplane, and with gyros serving an ever increasingly significant role in the science of flight, Eclipse-Pioneer Division of Bendix Aviation Corporation has embarked upon a program of developing a three gyro package that would serve as a basic reference along any axis. It is intended that the "cluster" will serve for any function requiring a stable reference and thus eliminate the need for the quantity of individual direct reading and control gyros present aboard modern aircraft. Basically the package will define a fix in space with reference to the axes of the aircraft or guided missile.

Design of the new unit includes a no-gimbal-lock feature which will permit complete 360 deg. maneuvers in all axes. The instrument may be erected to vertical and slaved to a magnetic heading, or erection and slaving may be cut off and the instrument operated as an unslaved system.

The 25 lb. instrument will occupy less than a half cubic ft. and will operate on 400 cycle, 115 v., and 28 v. dc power.

The design is such that there will be no gimbal error, and drift rate is expected to be a maximum of 1 deg. per hour. Of the three directional gyros used, two will be for defining pitch

and bank attitude, the third for defining azimuth.

The Three Axis Stable Platform suggests many advantages over existing systems in automatic control, including automatic pilot, radar control, and other navigational devices.

Eclipse Pioneer, Div. Bendix Aviation Corp., Teterboro, N.J.

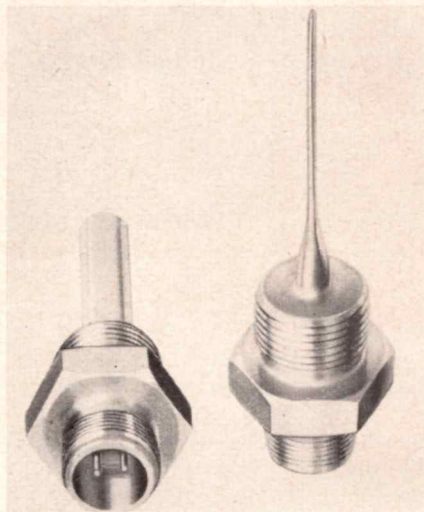


Breakaway Connector

Cannon Electric is the principal supplier of breakaway connectors for guided missiles, with many shell designs and contact arrangements and extraction means, including ball and detent, lever actuated, solenoid equipped.

These are Type GMA plug, right, and its mating receptacle. Complete assembly number GMA-50-28-CG-13/32. This type has a total of 50 contacts, 42 No. 16, 5 No. 8 and 3 coaxials for RG 58/U cable.

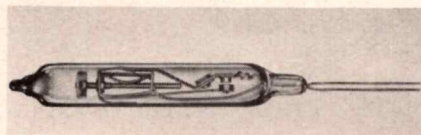
Cannon Electric Co., 3209 Humboldt St., Los Angeles, Calif.



Temperature Detector

One of many types, the detector illustrated has a response time of approximately 0.5 second in an agitated water bath. Accuracy in terms of temperature is better than ± 1.0 percent. Exceptional stability is achieved by hermetically sealed construction and use of pure nickel resistance element—drift is less than 0.5 percent over years of operation. Temperature range -100 deg. to +600 deg. F. Special Detectors available for operation to 1200 deg. F. Stainless alloys resist corrosion in missile applications involving hydrogen peroxide, etc.

Thomas A. Edison, Inc., Instrument Division, West Orange, N.J.

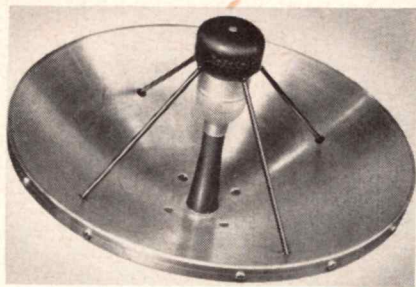


Precision Thermostat

Type S1-1A illustrated will control temperature setting to ± 0.1 deg. C. at low contact load. Temperature range is from -50 deg. to +150 deg. C.—calibration is made through glass after tip is sealed. Other thermostat types handle loads up to 1000 watts. Ideal for close temperature work pro-

use in 30-v., dc electric systems, and can be used in conjunction with Eclipse-Pioneer type 1588 voltage regulator.

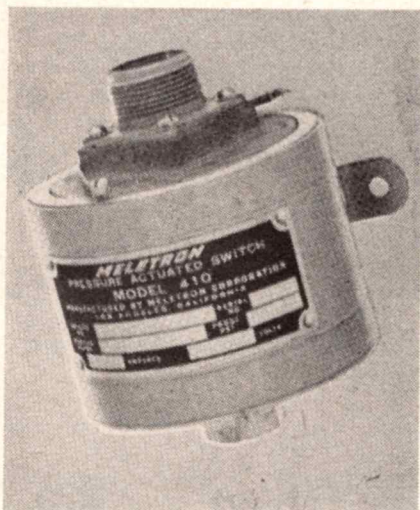
Eclipse-Pioneer, Div. Bendix Aviation Corp., Teterboro, N.J.



Lobing Antenna

The Sanders Associates' high information rate lobing antenna for use in airborne equipment and guided missiles. This antenna is capable of full operation under unusual developmental conditions and is typical of the microwave antenna and components developed by Sanders Associates.

Sanders Associates, Inc., 137 Canal St., Nashua, N. H.



Low Pressure Switch

The metal diaphragm pressure sensing capsule is completely sealed, leak proof and is suitable for liquids or gases. Using ambient as the reference pressure various diaphragm pressure sensing elements permit actuation anywhere within an adjustment range of 2 in. of water to 120 psi and proof pressures to 200 psi gauge.

Meletron Corporation, 950 N. Highland Ave., Los Angeles, Calif.

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HAYDON Elapsed Time Meter, Series 7008: 400 cycle a-c, hermetically sealed. Barrel diam., 1.525"; length, 2-45/64"; weight, 6 oz. Power consumption less than 3 watts. Indicates in units of 10s of hours up to 10,000, and repeats. Request "Engineering Bulletin No. 4".

*Trademark Reg. U.S. Patent Office

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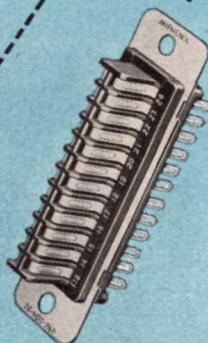
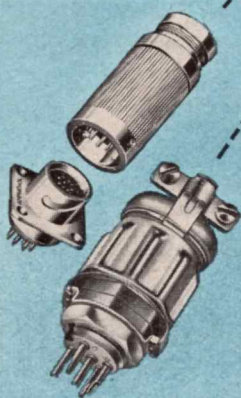
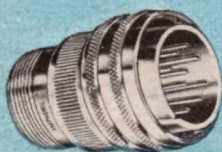
HAYDON Manufacturing Company, Inc.
3531 ELM STREET, TORRINGTON, CONNECTICUT

from: AMPHENOL for: AVIATION electronic applications

AMPHENOL manufactures over 11,000 separate components for electronics. Included in this extensive list—the most complete line in the industry—are AN and RF connectors, RG-/U coaxial cable, and special components for practically every electronic application.

AMPHENOL engineering for *quality* and production for *quality* results in both the excellent reputation and the industry-wide acceptance of the AMPHENOL component.

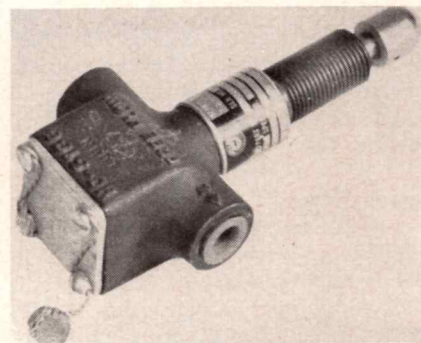
Insist upon the inclusion of AMPHENOL components in the electronic products of your company.



AMERICAN PHENOLIC CORPORATION
chicago 50, illinois

Class "S" Relays with small spring pile-ups.

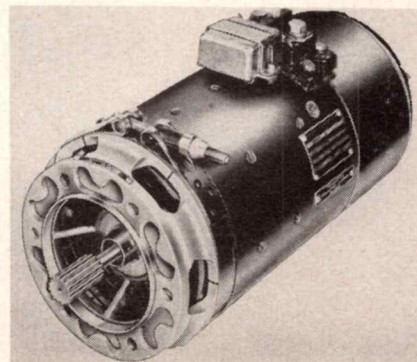
Automatic Electric Sales Corp., 1033 W. Van Buren St., Chicago, Ill.



Sequence Valve

HC-5144 Sequence Valve (Pneumatic) is a mechanically operated compact "on-off" valve, which also has the unique feature of free-reverse flow with only one moving part. Pressure level: 2300 psi; temperature -65 deg. F. to +160 deg. F. Zero leakage. Has Kel-F seat, features in-line ports. Total weight: 0.43 lb.

Air Associates, Inc., Teterboro, N. J.



Generator

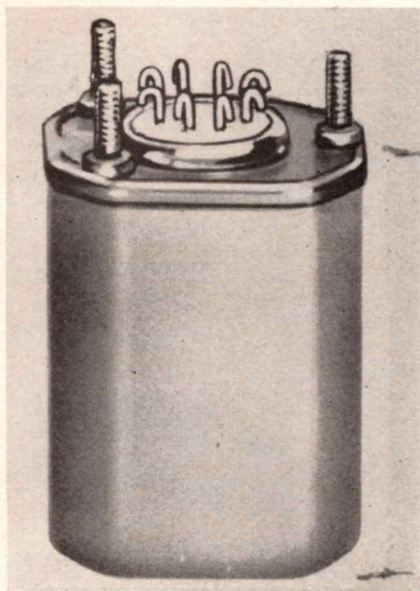
The Eclipse-Pioneer type 30E10-1 generator is a small diameter unit (6.5 in.) and is designed for use on turbojet propelled engines as an engine-driven source of dc power. It is nominally rated at 30 v., 400 amps. continuous duty over a speed range of 3100 to 8000 rpm and an altitude range up to 50,000 ft. Provision has been made to use a torsional vibration damper on the generator so that it can be adapted for use on reciprocating engines.

The generator is equipped with a military standard, quick-disconnecting mounting flange. The 16-tooth spline rotates in a counterclockwise direction when viewed from the mounting flange end.

This generator is recommended for

the Telecordex Type 8A. The Telecordex is a two-channel accumulator that may be connected directly to an electric typewriter, tape perforator, or IBM Summary Punch. The Contact Telereader is usually used with a Teleducer recording system. In other words, each measuring cross wire shaft is equipped with a helical potentiometer, and the voltage output of these potentiometers is converted to digital form by the Teleducer; and through the use of one of our Program Units of the Type 33 series, final recording may be made again with the electric typewriter, tape perforator, or IBM card punch.

Telecomputing Corporation, 133 E. Santa Anita Ave., Burbank, Calif.



Class S Relays

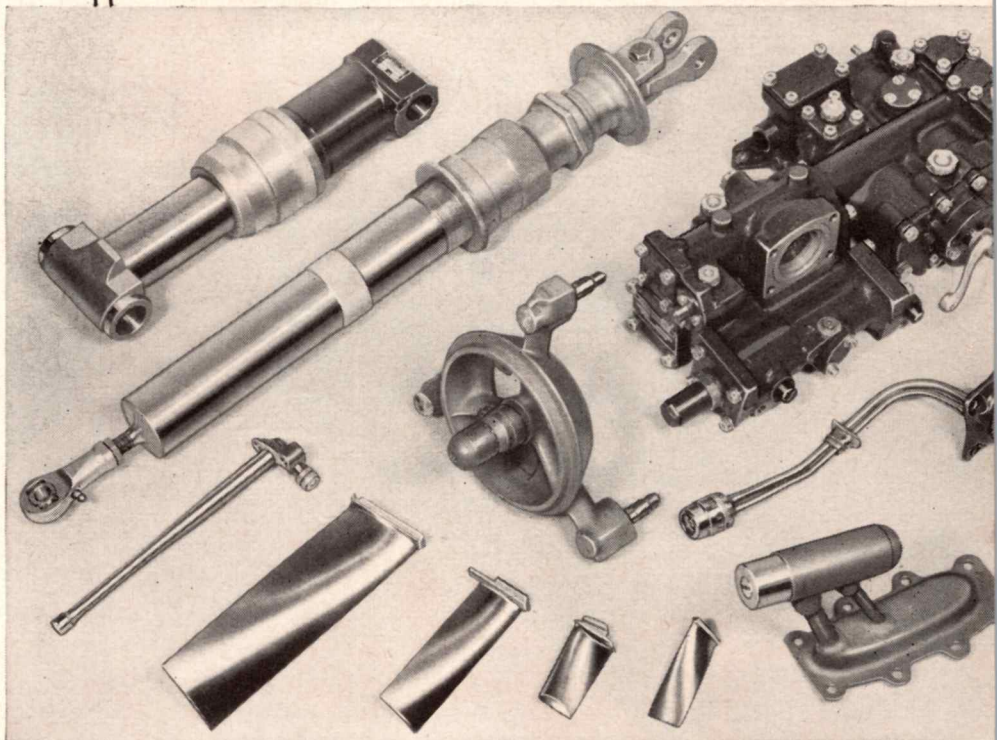
A Class "S" Relay is used in aircraft and similar applications where lightweight, small size, and resistance to shock and vibration are important requirements; or where minimum inductance and maximum speed of operation are essential.

Class "S" Relays are used to control: propeller pitch and engine synchronization, landing flaps and landing gear, automatic pilot equipment, guided missiles, radio channel selection, radio pulse repeating, bomb release.

The AE 2300 Enclosure accommodates one Series SQA Relay with 6 springs, or one Series SQD Relay with standard size coil and a maximum of 6 springs per pile-up. The AE 5200 Enclosure is a miniature enclosure which mounts the SQA Relay with 6 contact springs or less. The AE 600 Enclosure can accommodate up to 6

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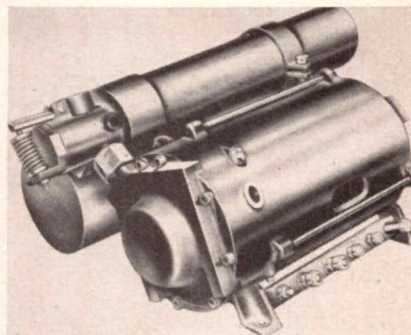
**MISSILE AND CONTROL
EQUIPMENT DEPARTMENTS**

NORTH AMERICAN AVIATION, INC.

Engineering Personnel

12214 Lakewood Blvd.

Downey, California



Power Package

Hamilton Standard Auxiliary Package for aircraft is a self-contained and self-regulated source of auxiliary hydraulic and electric power, using the energy from a solid propellant contained within its combustion chambers. Its range of operation extends from sea level to 50,000 feet.

Hamilton Standard Division, United Aircraft Corp., Windsor Locks, Conn.

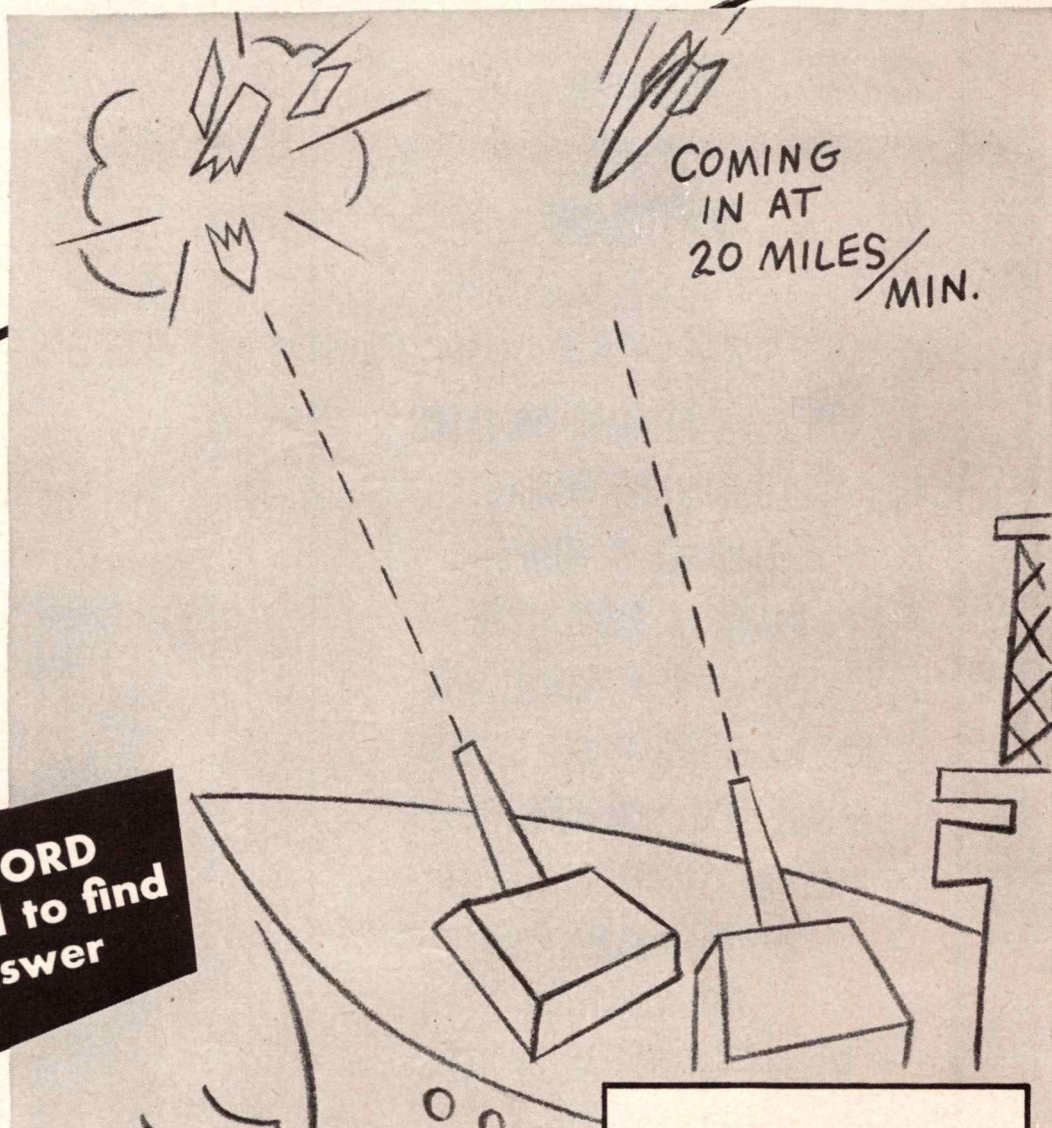


Telereader

The Universal Telereader differs from the Contact Telereader in that the former unit offers magnification of the record being read, a motor-driven record transport system, and a number of other refinements which make it a high-volume reading unit useful on a wide variety of records from 16 mm up to 12 in. wide. The Contact Telereader, on the other hand, is designed for use with those records which do not require magnification.

Both the Universal Telereader and Contact Telereader may be used with the same recording system, but usually the Universal Telereader is used with

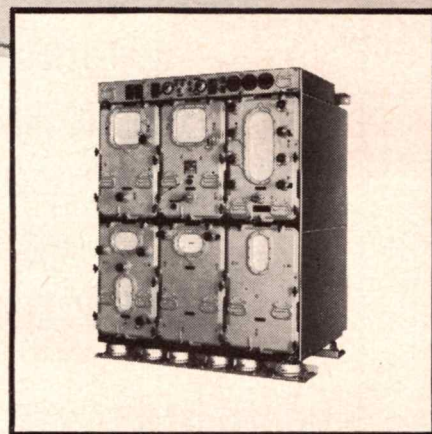
HOW TO HIT A SUPERSONIC MISSILE in flight



**...and FORD
was asked to find
the answer**

An enemy guided missile comes winging towards our task force... at speeds of up to 20 miles a minute. What kind of computer can predict and compute the necessary data fast enough to shoot down the missile... and be reliable every time? That was the problem posed to Ford Instrument Company engineers... and in cooperation with the Navy, they found the answer. Compact equipment, housed in easy-to-service units... that stand at the front line of our defense.

This is typical of the problems that Ford has been given by the Armed Forces since 1915. For from the vast engineering and production facilities of the Ford Instrument Company come the mechanical, hydraulic, electro-mechanical, magnetic and electronic instruments that bring us our "tomorrows" today. Control problems of both Industry and the Military are Ford specialties.



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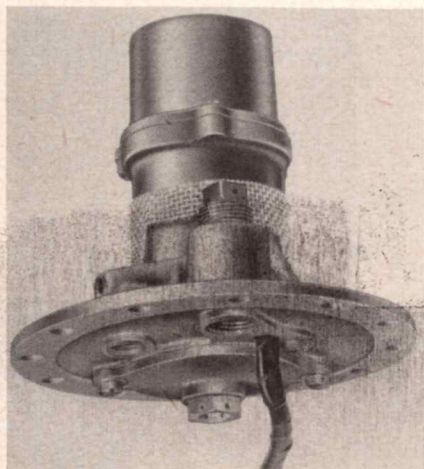
FORD INSTRUMENT COMPANY

DIVISION OF THE SPERRY CORPORATION
31-10 Thomson Avenue, Long Island City 1, N. Y.

22

stallation, variable delivery pressure control, low torque requirements, simplified engine and pneumatic drives, multi-cylinder design (which gives consistent, continuous high pressure pumping with critical loads distributed over large areas), and no gear or gear boxes on the electric drive.

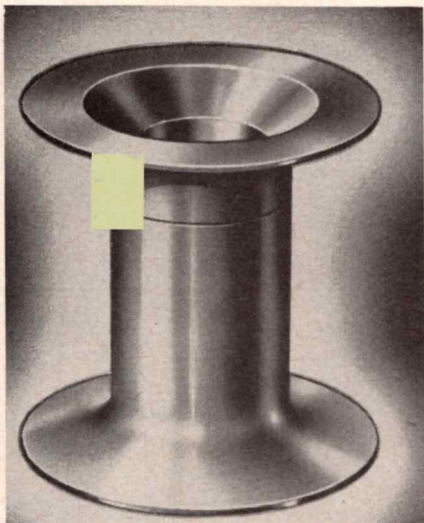
Hamilton Standard Division, United Aircraft Corp., Windsor Locks, Conn.



Hydraulic Pump

Pesco Model 012549-010 high speed hydraulic pump was developed especially for guided missiles. This pump is rated at 2.4 gpm at 12,250 rpm and 3000 psi discharge pressure pumping hydraulic fluid at 250 deg F. Weight—3 lb.

Pesco Products, Div. Borg-Warner Corp., 24700 N. Miles Rd., Bedford, Ohio.



Through-Bolt Spacers

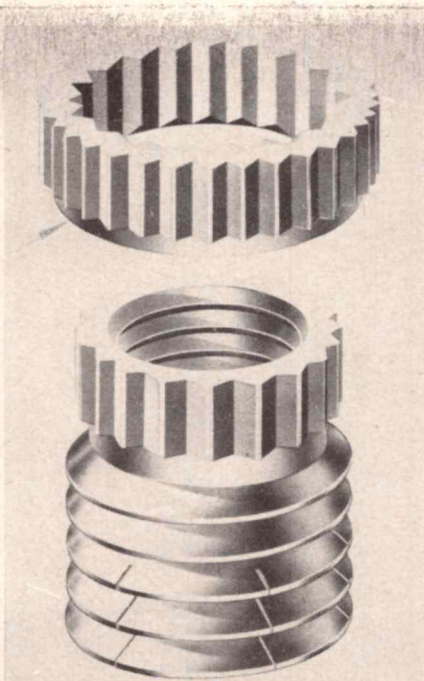
The Delron Fasco through-bolt spacer prevents crushing of sandwich

type panels at all fastening points.

One hundred fasteners weigh approximately 1/2 lb., the weight varying slightly with size. One through drilled hole with a simple press operation installs them. Flush installations of the spacer are possible and a counterbore style plug for a flat head screw is available.

Subassembly installation is done at rates exceeding 200 per hr. with a simple fixture on an arbor press. The spacer is self-retaining in the panel. If necessary for small production or installation of spacer at final assembly, a simple bolt and nut can be used to pull the Fasco into place.

The Delron Company, Inc., 5224 Southern Ave., South Gate, Calif.



Fastener

Rosan, Inc., manufactures a complete line of threaded fasteners which have the Rosan locking principle. All of these fasteners either have been used or could be used in missile design. The unique feature of the Rosan locking principle is the locking ring, or the serrated edge of the head of the bolt. By means of this feature each stud, insert, bolt, or nut is permanently and positively locked in place.

Normal threaded fasteners work loose in the first few seconds of flight because of the tremendous inertia set up in starting a missile off. With the expensive and complicated instrumentation of modern missiles whose

accuracy is dependent upon everything holding together until the missile has been delivered, the importance of the security of all fasteners can be realized. The Rosan clinch bolt, stud, insert, anchor nut, and its other threaded fasteners assure this security throughout the flight of the missile.

Rosan, Inc., 625 Coast Highway, Newport Beach, Calif.



Miniature Gyro

Pacific Scientific Co. has developed a group of miniature instruments incorporating dual precision potentiometer control signals. The group includes accelerometers, free gyros, rate gyros and linear potentiometers. The miniature accelerometer has the unique feature of allowing independent adjustment of the "G" range of the unit and natural frequency. This permits selection of a non-critical natural frequency and gives a smooth signal output under flight conditions with a saving in electrical filtering. Photo shows the new Pacific Scientific G30-2005-00 free gyro for attitude indication. Although this gyro is only 3 in. dia. and 4 in. long, it incorporates rugged construction using large, lightly loaded precision bearings and electrical caging and uncaging. Precision potentiometer output can be furnished on either or both gimbals. The unit uses a 400-cycle, 115-v. single or three-phase gyro wheel and has a drift rate of 1/4 deg. per min. max.

Pacific Scientific Co., 1430 Grande Vista Ave., Los Angeles, Calif.

Where's "Charlie"?

The "bird" will find him!

As it rockets along at supersonic speeds—high above the earth—its guidance system directs it unerringly to target "Charlie."

Electronics makes today's accurate missile guidance a reality—and *electronics* is the past, present and future of RCA.

For years, RCA has been working with the Armed Forces on design and

engineering of more accurate, more effective missile-guidance systems. The same RCA engineering facilities—from original planning to final production stages—are available for development of complete electronic systems of all kinds. For additional information, write to Government Department, Engineering Products Division, Radio Corporation of America, Camden, N. J.



GOVERNMENT DEPARTMENT

RADIO CORPORATION of AMERICA
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CAMDEN, N.J.





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Yours for the asking, the new booklet (No. 800) offers the answers to many exacting and unusual problems of mounting electronic equipment in supersonic aircraft and missiles.

The booklet includes engineering data and specific examples of various types of mounts and engineered mounting systems currently being applied and used in important missile projects. Send for your **FREE** copy today.

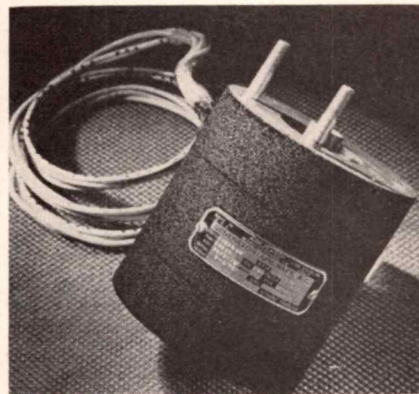
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Vibration Control Engineers

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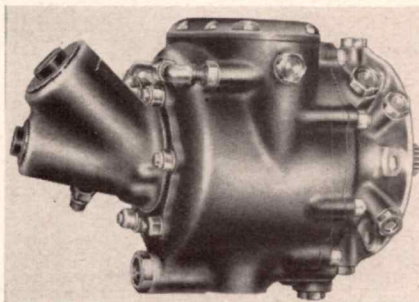
Pesco Products, Div. Borg-Warner Corp., 24700 N. Miles Rd., Bedford, Ohio.



Generator

Induction generators built by AiResearch Manufacturing Company supply alternating current to guided missiles. Exceptionally compact, this unit weighs only 4¾ pounds and is less than half the size of an automobile generator. Storage qualities make induction generators well suited for missiles. Designed on the principles of the induction motor, they are simple, containing no rotating windings, magnets, brushes, slip rings, commutators or DC exciters. Other advantages are that they are rugged, have inherent voltage regulation, operate at extremely high altitudes and greatly reduced weight.

AiResearch Manufacturing Company, 9851 Sepulveda Blvd., Los Angeles, Calif.



Hydromatic Pump

This Hamilton Standard Pump for aircraft is a compact, light-weight, high speed unit which provides 6300 rpm continuous duty or up to 9000 rpm for intermittent duty. It weighs less than 20 lb. and occupies less space and is 20 to 30 percent lighter than equivalent low-speed models. Among its other features: Flexibility of in-

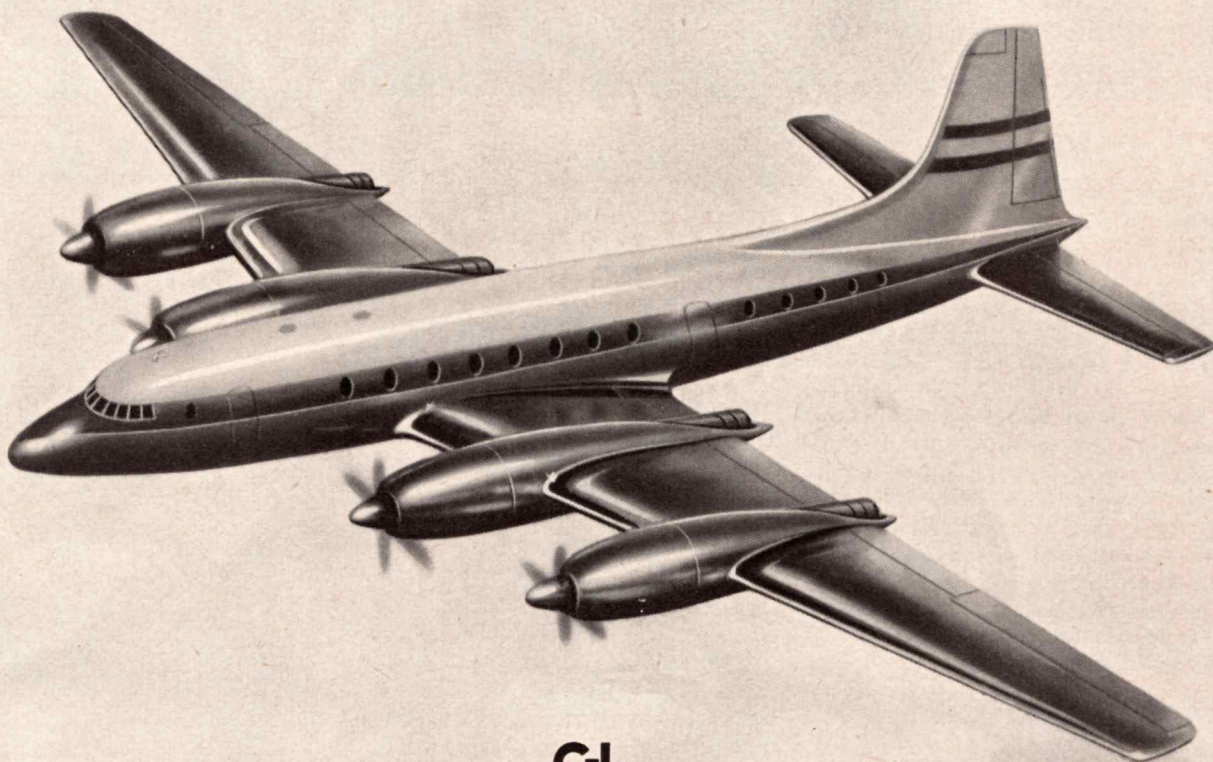
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CANADAIR'S PRODUCTION ABILITY

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CANADAIR

LIMITED, MONTREAL, CANADA

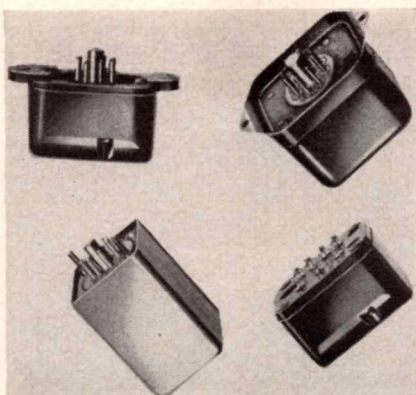
A subsidiary of GENERAL DYNAMICS CORPORATION, New York, N.Y. — Washington, D.C.

CA54-24

quency response tests, insulation proof tests, current proof tests, and various hydraulic flow tests. A DuMont oscilloscope is used with a Servoscope for the phase lag or frequency response test.

A 300 psi, 5 gpm pump is used to provide the necessary hydraulic flow. Micronic filtration is provided in both the high and low pressure circuits. Oil temperature control permits continuous duty.

Greer Hydraulics, Inc., 454 18th St., Brooklyn, N. Y.



Ultra-Sensitive Relays

Extremely sensitive polarized dc relays for many electronic, photo-electric, servomechanical, and other balance detecting bridge circuits eliminates the need for vacuum tubes in many applications. Relays are available in a wide range of coils, enclosures, and mountings. Has high speed response. Sensitivities from 50 microwatts to over 100 milliwatts. Applications include use in automatic control circuits of drone targets and missiles.

Barber-Colman Company, Rockford, Ill.



They're in stock when wanted at UNIVERSAL

Whether you order Army-Navy approved clamps bare (AN 742 series) or the new cushioned MS 21919, Universal's quantity runs assure quick delivery and "on-spec" characteristics at all times. Available in carbon steel, aluminum alloy and stainless steel. Note the large, easily read type identifying the clamp—time saver in both

production and stockroom.

UNIVERSAL'S years of design and production of airframe components establishes this company as a major source for tool making, stamping, welding, sub- and finished assembly. (Home of the famous Universal Aircraft Fuel Filler Caps.)

Nationwide service. For clamps—all sizes and types—contact UNIVERSAL

A WORLD OF KNOWHOW

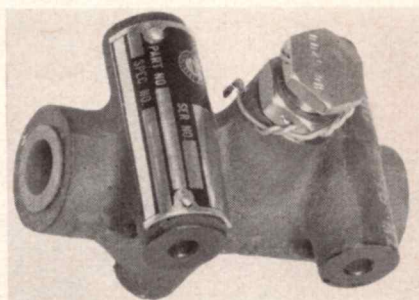
TOOLS • DIES • METAL STAMPINGS • AIRCRAFT PARTS



Universal
METAL PRODUCTS, INC.

2311 West Orange Street,
Alhambra, California
CUMberland 3-3115

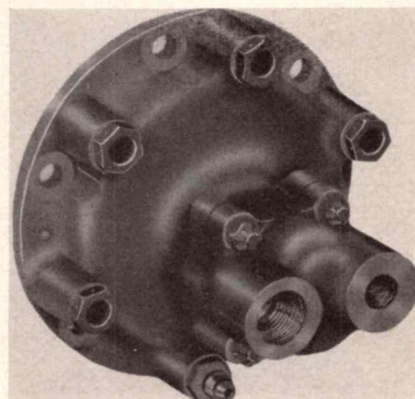
Kansas City, Mo. Branch: Congress Building, 3527 Broadway



Resistor

HC-5146 One Way Restrictor (Pneumatic) is a small, hand adjustable restrictor valve, with free flow in the reverse direction. Light spring loaded ball check built into restricting screw to accomplish operation. Pressure: 2300 psi, temperature -65 deg. F. to +160 deg. F. In-line ports. Weight: 0.29 lbs.

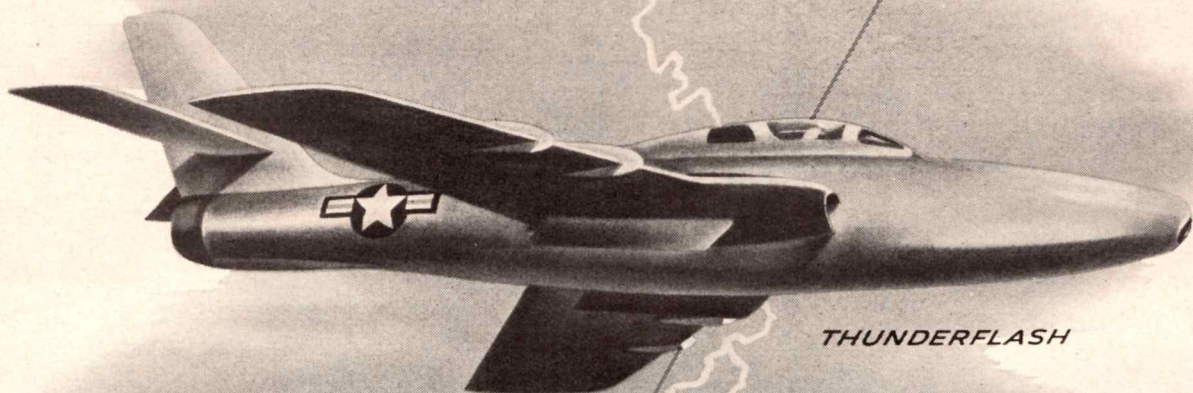
Air Associates, Inc., Teterboro, N.J.



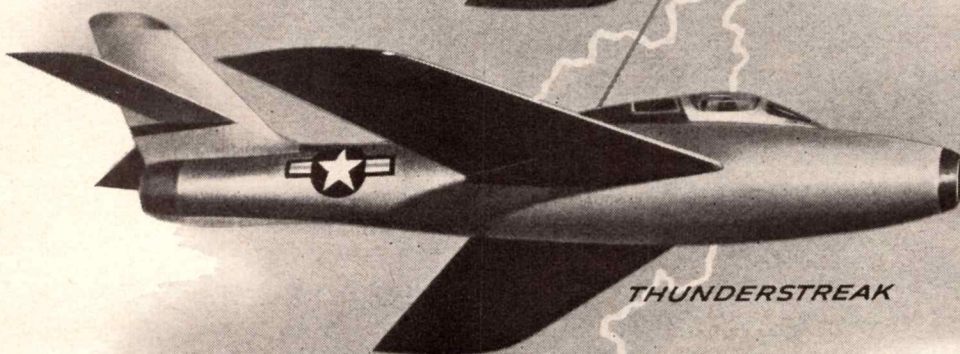
Booster Pump

Pesco Model 122723-100 electric motor driven, centrifugal, submerged fuel booster pump is A.F. Type B-26, rated 300 gph flow at 10 psi, weighing only 2.7 lb. Used in turbojet powered missiles. This pump is one of the family of small booster pumps Pesco manufactures for small guided missiles, helicopters, and executive aircraft fea-

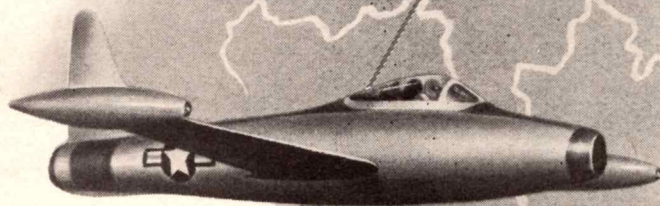
SUPERIORITY...



THUNDERFLASH



THUNDERSTREAK



THUNDERJET



THUNDERBOLT

For more than a decade Republic has designed and built a succession of Thunder-craft fighters and fighter bombers for the U.S.A.F. which have proven without peer. >> The mighty THUNDERBOLT of World War II established a proud record in combat as the sturdiest, deadliest "work horse" of its time . . . the THUNDERJET which earned its fame as a fighter bomber during the Korean War is maintaining its own fine position of leadership with our Air Force and our allies in NATO. >> The new THUNDERSTREAK, now in service, and the THUNDERFLASH, its photo-reconnaissance counterpart, with an entirely new range of speeds and effectiveness emphasize that each product of Republic's know-how maintains superiority of performance in its field.

REPUBLIC  AVIATION

FARMINGDALE, LONG ISLAND N. Y.



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reliable
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*for
guaranteed
dependability*

TURBO MORE THAN MEETS THE SPECS. in all respects

To meet
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new Turbozone-40 Vinyl Plastic Tubing

New TURBOZONE 40 is Heat resistant . . . Cold resistant (to -90° F.) . . . Flame-proof. (meets flammability requirement of MIL-I-631B) . . . Flexible, for snaking . . . Strong (tensile strength 1800 p.s.i.) . . . Fungus resistant . . . Moisture-proof . . . Durable . . . Transparent (for easy identification of color coding).

To meet
**MIL-I-3190
Class "H"**

Turbo 117 Silicone Rubber Tubing

Twists — Bends — Knots Durable Silicone Rubber Peel-proof Coating fused to Fibrous Glass Braid . . . Lasting dielectric strength . . . Humidity resistant . . . Oil resistant . . . Flame resistant . . . Non-corrosive . . . Fungus resistant . . . Heat resistant (to 500° F.) . . . Cold resistant (flexible at -100° F.) . . . Won't Crack . . . Won't Craze.

To meet
MIL-W-16878A

Component and Instrument Hook-Up Wire

Maximum High Temperature Protection
Outstanding Electrical properties — Primary Insulation resistant to Water, Oils, Fuels, Hydraulic Fluids, Ethylene Glycol, Alcohol, Dilute Acids, Alkalis and Fungus. Maximum rated voltages: TYPE "B" — 600 v. (r.m.s.); TYPE "C" — 1000 v. (r.m.s.); TYPE "D" — 3000 v. (r.m.s.). TYPE FF — SILICONE RUBBER INSULATED.

To meet
MIL-W-12349

Monochlorotrifluoroethylene insulated . . . Tough Abrasion Resistant . . . Continuous operating from -55° C. to 135° C. . . Superlative moisture resistant. Working voltage—600 v. (r.m.s.). Other Aircraft and Electronic Wires and Cables such as MIL-W-5086, MIL-C-7078, MIL-W-5274A, JAN-C-17A and JAN-C-76 are also available.

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operation. Integral gear heads, radio noise filters, and other special features can be supplied.

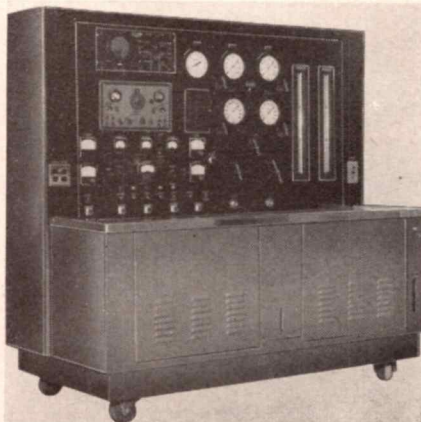
Barber-Colman Company, Rockford, Ill.



Miniature Servo Gear Motor

Available in various rpm and torque combinations, EAD's Servo Gear Motors are built for minimum inertia and maximum torque in a compact unit. The gears are precision cut and each stage is mounted in precision ball bearings.

Eastern Air Devices, Inc., 385 Central Ave., Dover, N. H.

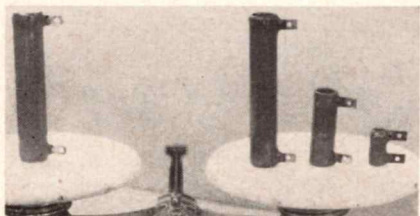


Servo Valve Test Stand

This Greer Model SVM-900 is a hydraulic test stand to test the function of a Moog two-stage servo valve as a component, and as part of a missile control system. The test stand has all the electronic and hydraulic equipment necessary to make dynamic fre-

Gyro Sets for sensitivity in three planes. These units are available with ac or dc motors and also as hermetically sealed units.

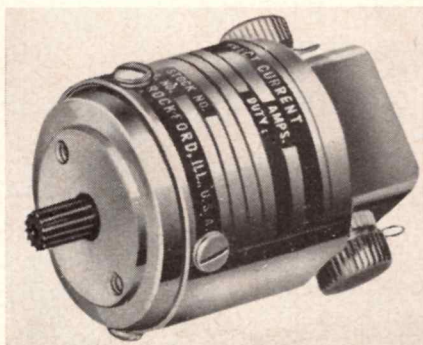
G. M. Giannini & Co., Inc., 918 E. Green St., Pasadena, Calif.



Power Resistor

General Electric has started production of a new coreless power resistor representing a significant development in the field. The new resistors are up to 50 percent lighter than conventional types and are the first designed to meet characteristic "V" of the MIL R26B specification. Immediate application for the resistors will be found in military equipment where reduced size and weight is so important, and will be followed by types for commercial use. The new G-E product, priced competitively, will be marketed under the name "Kor-les Cool Blue Power Resistor" and will be available in standard resistance values within MIL types RW 29, 30, 31, 32, 33, 34 and 35.

General Electric, Electronics Park, Syracuse, N. Y.



D-C Motors

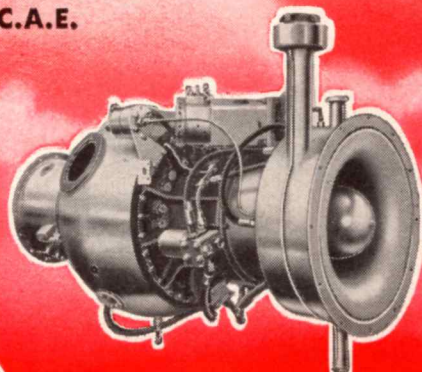
Compact, powerful sub-fractional horsepower dc motors designed for many servomechanism, programming, and geared-head devices; blower drives; and generators have new symmetrical rotor winding resulting in greatly improved motor performance, efficiency, superior commutation, and low radio noise interference. Available in several frame sizes, a wide range of speeds, for 6 to 115 v. dc

Get power

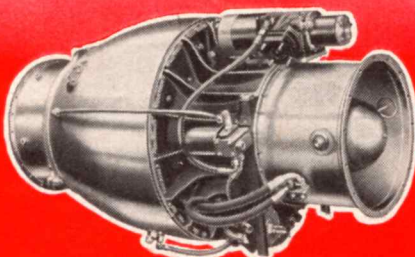
FOR THE AIR AGE



These Continental gas turbines, now in production at C.A.E., are finding acceptance in a steadily-widening range of applications where shaft turbines, air generators or turbo-jets are required. Manufacturers with present or prospective need for units of exceptional dependability are invited to bring their problems to C.A.E.



MODEL 140 AIR GENERATOR
Supplies up to 2000 cu. ft. per min., at 50 p.s.i. In production, for use as starter for large turbines; numerous other uses in prospect.



J69 TURBO-JET

Jet power for target and trainer aircraft, and auxiliary power for transports and bombers. Develops up to 1,000 lbs. thrust; still higher output in prospect.

ENGINEERS AND OTHERS DESIRING CAREERS IN THE FIELD OF SMALL TURBINES: WRITE TO C.A.E., STATING BACKGROUND AND TYPE OF WORK DESIRED.

CONTINENTAL AVIATION & ENGINEERING CORPORATION

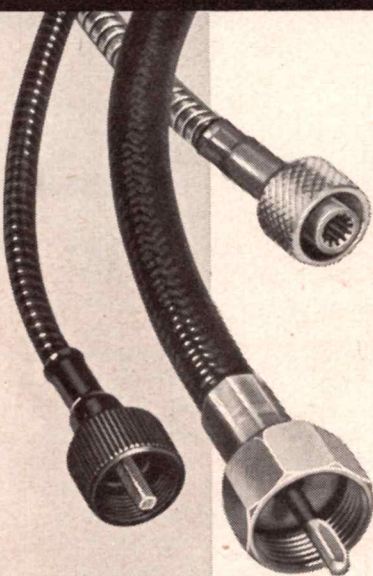
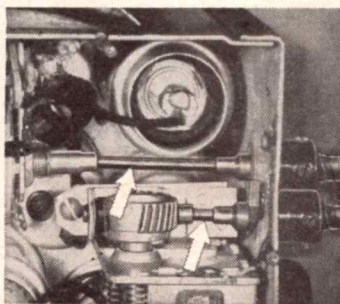
1500 ALGONQUIN AVE., DETROIT 15, MICHIGAN

SUBSIDIARY OF CONTINENTAL MOTORS CORPORATION

COST-SAVING IDEAS  FOR DESIGN ENGINEERS

S. S. WHITE FLEXIBLE SHAFTS ELIMINATE ALIGNMENT AND VIBRATION PROBLEM

By coupling the tuning knobs to variable circuit elements with S.S.White remote control flexible shafts, the designer of the radio equipment illustrated was able to eliminate all problems of alignment and thus simplify assembly. The shafts also dampen vibration, preventing it from being carried to the sensitive parts of the circuit.



WHAT ABOUT YOU?

You'll find S.S.White remote control flexible shafts the answer to many similar design problems. It will pay you to investigate their possibilities in your own product. Our engineers stand ready to answer your questions. There's no obligation of course.

BULLETIN 5306 has basic information and data on flexible shaft application and selection. Send for a free copy. Address Dept. A.



R-2

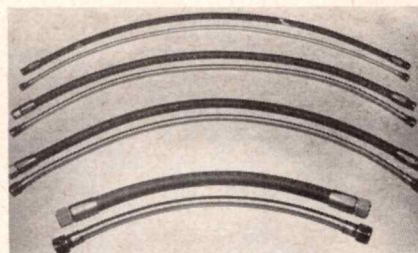
THE S.S. White INDUSTRIAL DIVISION
DENTAL MFG. CO.

10 East 40th Street
NEW YORK 16, N. Y.

Western District Office • Times Building, Long Beach, California

limits: 360 deg. in roll and pitch with controlled tumbling of the pitch axis at near 90 deg. Erection device: A two-ball erection system maintains the gyro in a vertical position to within $\frac{1}{4}$ deg. of vertical position with respect to the earth. Caging: From any position at full rotor speed in less than 45 seconds.

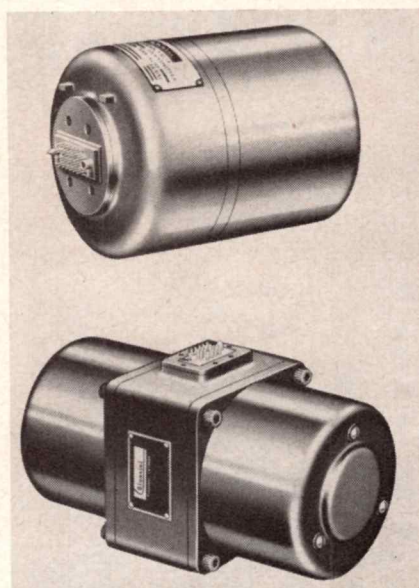
Eclipse-Pioneer, Div. Bendix Aviation Corp., Teterboro, N.J.



Missile Hose

Comparison between conventional hose and the new "Fluoroflex-T" R500 hose (made from duPont's fluorocarbon resin) shows that in each size the Resistoflex R500 hose (the lower in each pair) is smaller in outside diameter. The new hose also weighs approximately only half as much as the conventional hose in comparable size. It is exceptionally inert to corrosive liquids and withstands temperature extremes from -100 deg. F. to over 450 deg. F.

Resistoflex Corp., Belleville, N. J.



Free Gyro

New Giannini Universal Series Gyro, which is available as free directional or vertical units, and also available as



National Seamless Tubes

"back-up the blast" of Navy Jet's guns



NATIONAL USS Stainless Seamless Tubes are being used as gun blast tubing on the F2H-3, a McDonnell jet interceptor. The actual gun openings shown on the photograph are castings. But directly behind them, mounted over the machine guns' muzzles, are the gun blast tubes.

The job of the blast tube is to restrain high pressures caused by the firing of the gun, and to prevent the backflow of muzzle gases into the plane itself. These gases are highly explosive, and must be kept from the inside of the plane.

Previously, the $1\frac{1}{16}$ " OD x $1\frac{1}{8}$ " ID gun blast tubes were machined from bar stock. National Seamless Tubing, however, pierced from solid billets of USS Stainless Steel affords the absolute uniformity of wall strength required for such a heavy-duty application.

Shelby Seamless Tubing, made by National Tube, is ideal for all types of aircraft applications—landing gears, engine mounts, wing spars, longerons, fuselage struts, tail assemblies, etc. Shock-absorbent Shelby Seamless combines to the highest degree the desirable qualities of strength, safety and workability. It is uniform throughout and dimensionally accurate, possessing excellent machining and superior welding properties. Available in a wide range of diameters, wall thicknesses, various shapes and steel analyses, Shelby Seamless is produced to exacting standards by the world's largest manufacturer of tubular steel products. Bring your tubing problems to our engineers. They are here to help you.

NATIONAL TUBE DIVISION
UNITED STATES STEEL CORPORATION, PITTSBURGH, PA.
(Tubing Specialties)

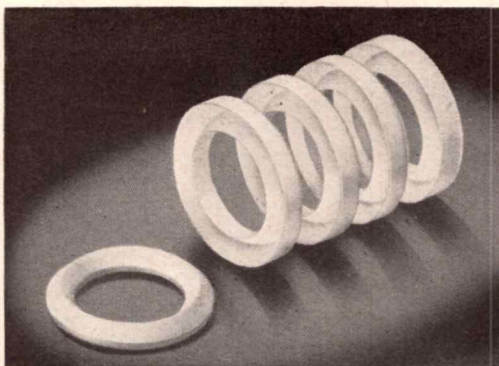
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO, PACIFIC COAST DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS

SHELBY SEAMLESS Aircraft Tubing



UNITED STATES STEEL



the **V**-Ring Packing no hydraulic fluid can attack

Chemiseal V-Ring Packing is made of pure duPont TEFLON to outlast other packing materials many times over. Ideal for manual or automatically operated valves.

Distinctive tapered V-design offers greater flexibility and resiliency—providing the necessary seal at low gland pressure and reducing torque required to operate valve.

An extremely anti-hesive, anti-friction, non-absorbent, chemically inert, non-flammable material for service temperatures from -110°F to plus 500°F . Offered in sets with square-end TEFLON adaptors. Ask for Bulletin No. TP-1053.

Other U.S.G. Engineered Packings...



include Chemiseal synthetic rubber "O"-Rings—and Chem-o-green Spiral back-up Rings—companion products sold as a "Packing Package" for all commercial and AN requirements. Ask for Catalog OB-1152.

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STATES
GASKET
COMPANY**

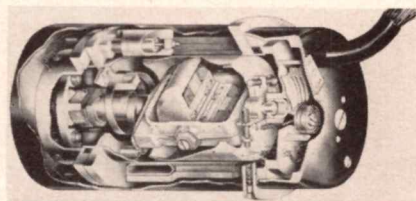
CAMDEN 1 • NEW JERSEY
FABRICATORS OF duPont TEFLON,
Kellogg KEL-F AND OTHER PLASTICS
Representatives in Principal
Cities Throughout the World



cycle unit is made for 1, 2 and 3 cycle.

Modifications include hysteresis synchro, servo, and gear types.

Eastern Air Devices, Inc., 385 Central Ave., Dover, N. H.



Rate Gyro

Doelcam Type K Rate Measuring Gyroscopes are precision instruments for the measurement of absolute angular rates where high accuracy and superior dynamic response are essential. They are used in numerous guided missile control and homing systems and for the flight evaluation of the latest military aircraft.

The unit has a 1000:1 ratio of gyro angular momentum to gimbal inertia, damping ratio constant within 15 percent over operative temperature range of -67°F . to $+185^{\circ}\text{F}$., signal proportional to input rate within 0.25 percent of full scale and a high signal-to-noise ratio and excellent resolution with variable reluctance pickoff.

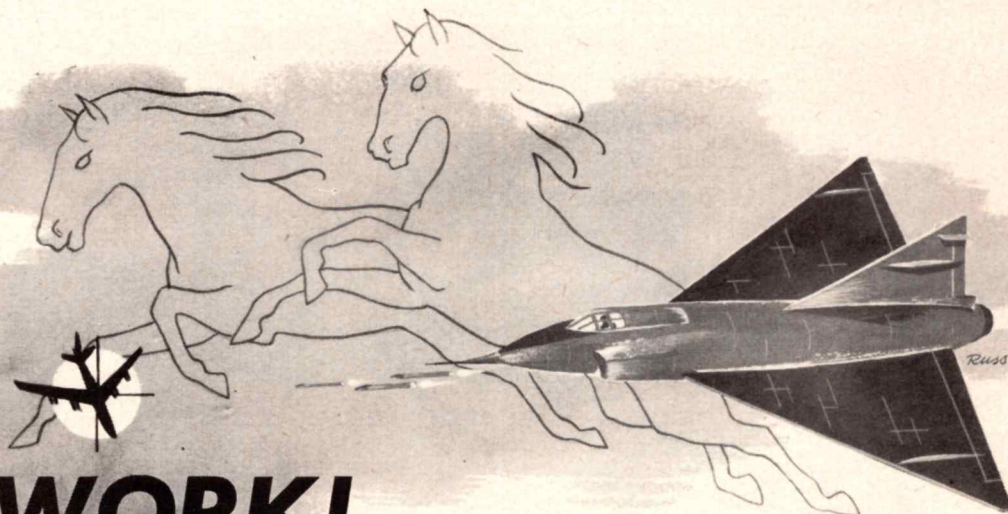
Doelcam Corporation, 1400 Soldiers Field Rd., Boston 35, Mass.



Vertical Gyro Transmitter

This instrument is designed for use as a remote vertical reference where vertical stabilization is required. It is essentially an electrically driven, vertical-seeking gyro with separate Autosyn transmitter pickoffs on the pitch and bank axes. Sealed in an aluminum case against environmental conditions.

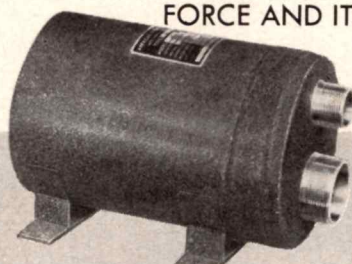
Operating temperature range: -55°C . to $+70^{\circ}\text{C}$. Operational



TEAMWORK!

MINIATURE GYROS ARMAMENT INTERVALOMETERS "MIGHTY MITES" of the all-time championship team

Every guided missile, every military aircraft relies in some way on one of the "MIGHTY MITES" of the control system. AMERICAN GYRO CORPORATION is proud that the many types of miniature gyros and intervalometers developed and produced by them are indeed "MIGHTY MITES" of the greatest team ever formed, the UNITED STATES AIR FORCE AND ITS CIVILIAN SUPPLIERS.



INTERVALOMETERS

Complete automation for firing systems — provided by a "MIGHTY MITE" only $7\frac{3}{4}$ inches long, $5\frac{1}{2}$ inches in diameter and 4 pounds in weight. An exclusive, positive-interlock system assures complete safety.



GYROS

American Gyro Corporation miniature rate and two-axis gyros use full flotation construction; thus, under the greatest extremes of usage, they are able to adhere to the most exacting specifications for airborne units.

PRODUCTION ITEMS OR RESEARCH AND DEVELOPMENT

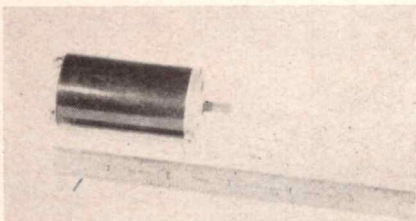
Call on American Gyro Corporation for aid in the solution of any of your problems involving gyros, intervalometers or other units of stabilization and control systems. Here you will find the right answer for you, either in presently stocked items, or in the fertile, ever-active minds of the outstanding engineers who help make the AMERICAN GYRO CORPORATION the leader in its field.

For detailed information concerning help with your particular problem, write—

AMERICAN GYRO CORPORATION

3030 Nebraska Ave. (Department A), Santa Monica, California





Generator

The Globe Generator is similar to the Globe "Moto-Mite", (a permanent magnet motor). The design has been refined specially for generator application to provide units of high voltage output per unit of speed. Effort has

also been made to reduce the "slot-lock" effect and to reduce inherent friction to obtain minimum starting torque.

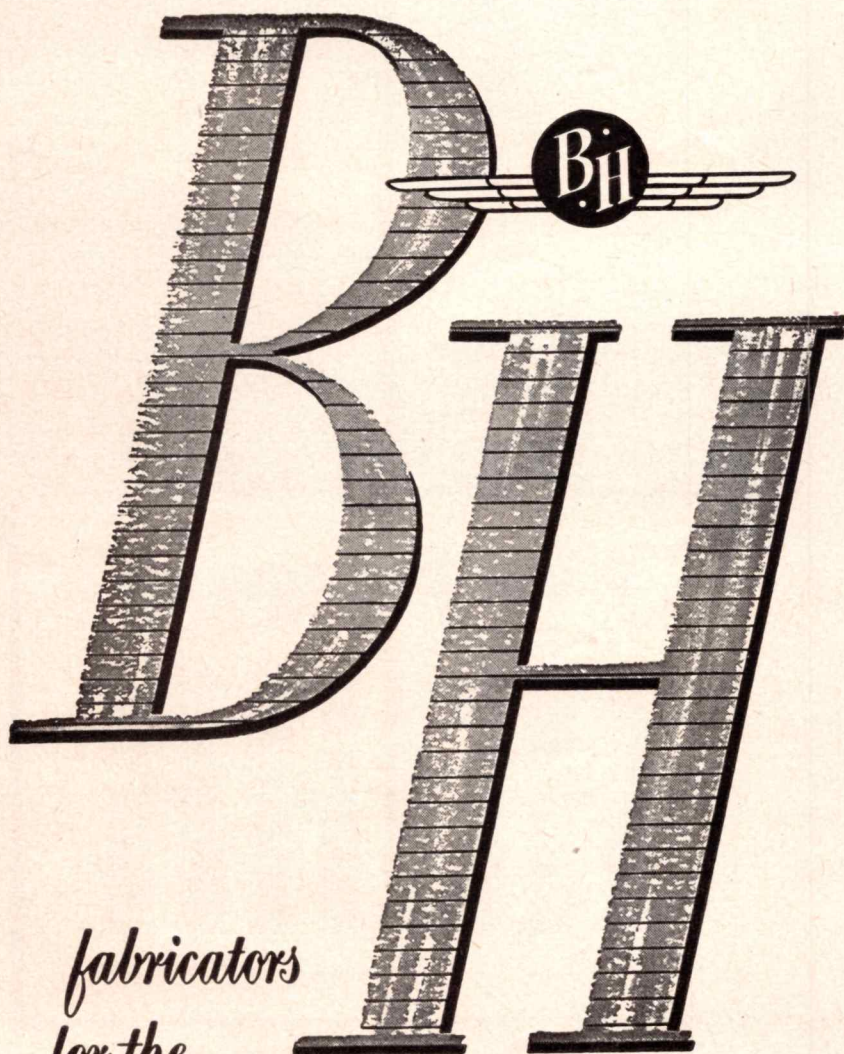
These features make the Globe generator especially useful as a rate device in servo systems, since it represents an extremely small, light weight package with sufficiently high output to provide good sensitivity.

Since these generators are permanent magnet units, slot lock and voltage output are proportional to magnetization. Therefore, maximum output is incompatible with minimum slot lock, or starting torque. As an ex-

ample, a specific unit can produce 0.7 v. per 100 rpm. with a starting torque of 0.15 oz. inches, or can produce 1.7 v. per 100 rpm. with a starting torque of 0.5 oz. in. The output, including ripple content under both these conditions, is shown on the reverse side.

All outputs are based on high impedance loads (approximately 1000 ohms per v. minimum) and it must be correspondingly reduced if appreciable current is required. Most units can be loaded to 50 milliamperes or higher, depending on the windings.

Globe Industries, Inc., 1784 Stanley Ave., Dayton 4, Ohio.



*fabricators
for the
aircraft industry*

B.H. AIRCRAFT CO. INC.

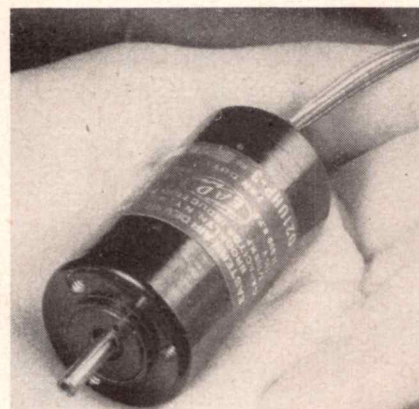
FARMINGDALE, NEW YORK



Varistors

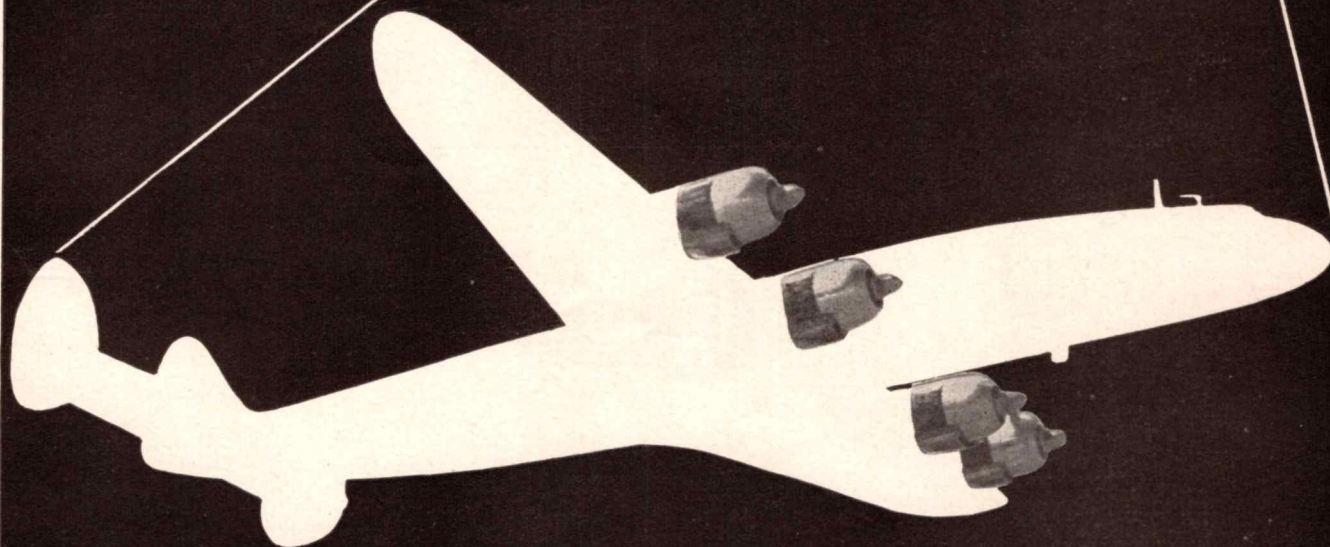
IRC Varistors are available in a large selection of enclosures: hermetically sealed glass or metal, phenolic or molded housings and unmounted cells to be directly mounted by the customer. The hermetically sealed Varistors will operate continuously under adverse conditions such as high humidity, dust, corrosive fumes, etc. When required, Varistors can be treated to eliminate microphonics. They can be furnished with multiple cell assemblies for voltages up to 200 v. For special applications where inverse characteristic can be used, units up to 8000 v. can be supplied.

International Resistance Company, 401 N. Broad St., Philadelphia, Pa.



Miniature Motor

Where size and weight are at a premium EAD's 1 in. diameter motor is valuable. It is designed for fans, blowers, instruments, controls and drives, both in standard and high temperature—high altitude versions with a nominal rating of 1/100 hp this 400



LOCKHEED SUPER CONSTELLATION

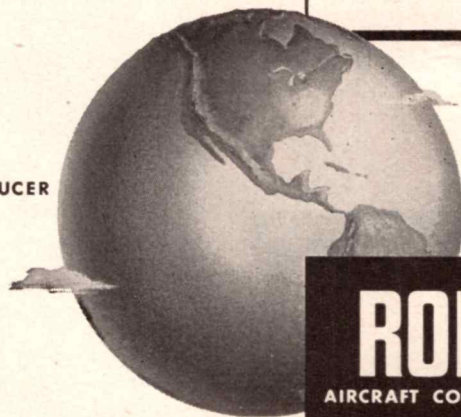
Rohr builds more power packages for airplanes than any other company in the world — and this picture shows the Rohr-built power packages on the wing of the big, beautiful Lockheed Super Constellation. In addition to producing power packages for the world's leading commercial and military planes, Rohr Aircraftmen are currently making more than 25,000 different parts for all types of aircraft.

power packages by

ROHR

WORLD'S LARGEST PRODUCER

OF READY-TO-INSTALL POWER PACKAGES FOR AIRPLANES

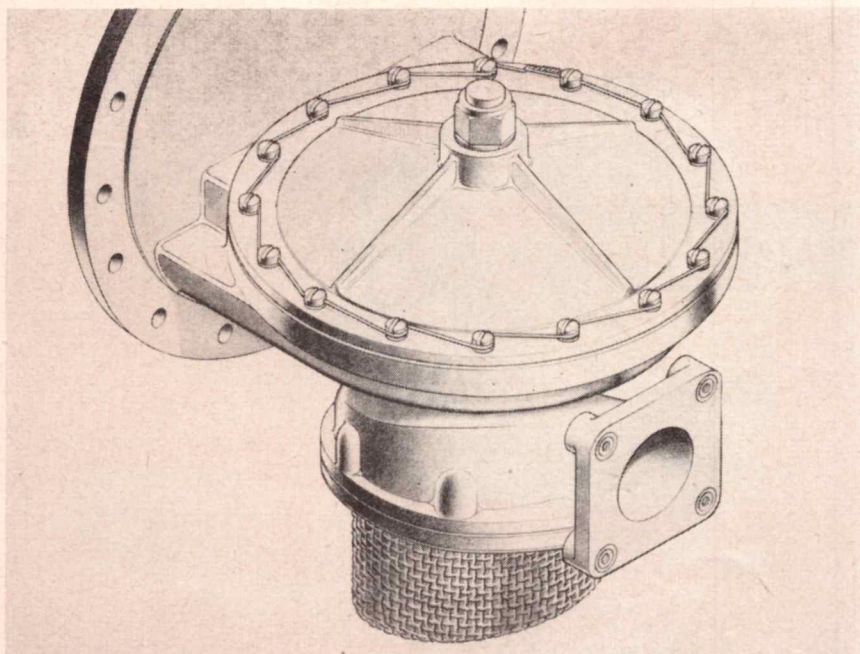


ROHR

AIRCRAFT CORPORATION

CHULA VISTA AND RIVERSIDE CALIFORNIA

MISSILE EQUIPMENT



HYDRO-AIRE'S new LO-U/C turbine has a turbine wheel that mounts on the main shaft of the accessory itself and requires no additional bearings. When compared with conventional designs, the unit provides superior thermodynamic performance at low blade speeds . . . when operating at high pneumatic energy levels.

This last design feature is vital, since the turbine rpm is limited by the accessory design speed.

The LO-U/C turbine has inherent aerodynamic speed limitations which eliminate the need for an overspeed sensing device, shut-off valve and actuator.

The energy transfer principle on

which this unit operates makes possible the use of a simplified blade form adaptable to extrusion technique. This design feature coupled with few requirements for close tolerances, facilitates inexpensive quantity production. The turbine housing is readily adaptable to integration with the housing of the accessory package.

Hydro-Aire HY-V/L (for high vapor-liquid ratio) fuel pump combined with the new turbine produces a turbine-driven fuel transfer pump (see picture) combining all the design advantages of the new turbine with the outstanding features of the pump. Operating at a rated speed of 12,000 rpm, the turbine and pump are exceptionally well matched, each providing near optimum performance across a wide range. At all stipulated flight conditions and altitudes, the pump exceeds specified weight flow and head requirements, exhibiting in addition a high vapor handling capacity. The turbine requires no controls and performs at all times under full compressor bleed pressure, limiting its own flow rate aerodynamically to values well within those set forth in the design specifications.

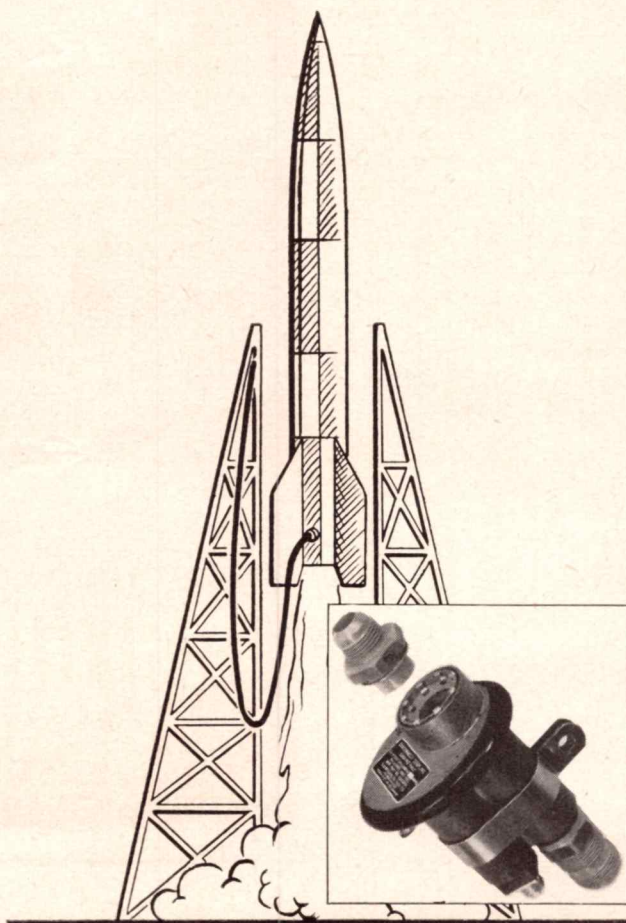
Hydro-Aire, Inc., Winona Ave., Burbank, Calif.

Remote Control Couplings

On launching stands all fluid and electrical lines are connected to the "bird" and are disconnected by remote control upon firing. It is vital to the complete operation that these couplings be positive, foolproof and reliable. E. B. Wiggins has developed electric solenoid actuated, pressure actuated by hydraulic or pneumatic means, and lanyard actuated disconnect couplings. As an added safety feature the electric solenoid and pressure actuated couplings can also be operated by a manual trigger.

These remote actuated couplings are designed to couple fluid and electrical lines. Typical examples being liquid oxygen, alcohol, ammonia, fuel, standard AN electrical inserts, hydraulic and other lines. These Wiggins Couplings can be self sealing with a valve action in each half or open type depending upon the particular application or the need of the designing engineer.

E. B. Wiggins Oil Tool Company, Inc., 3224 E. Olympic Blvd., Los Angeles 23, Calif.

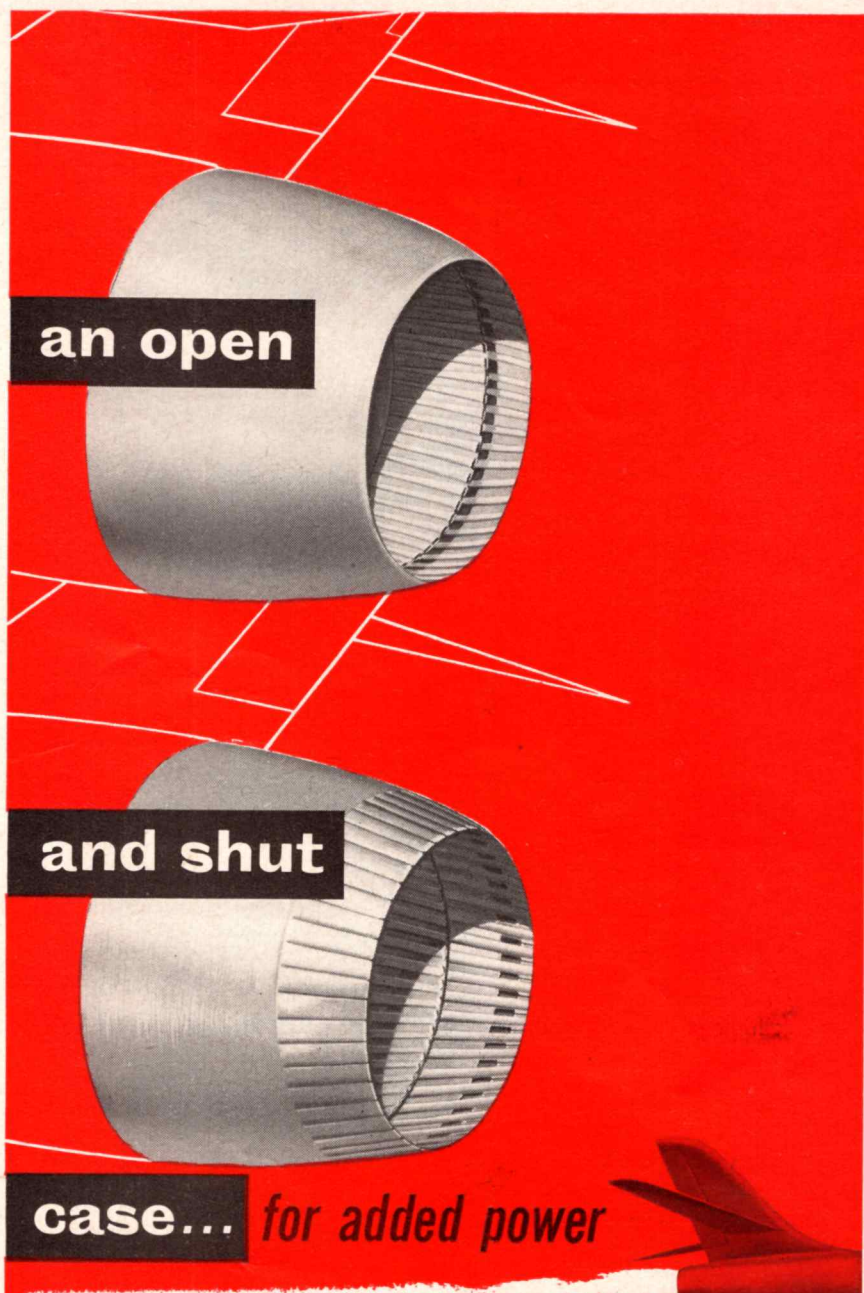


Some of the more recent developments in rocket applications lie in the field of high-pressure molding of glass-reinforced phenolic resins. Many small, non-structural items have been constructed in this fashion. The promise of light weight, good, reproducible physical properties and high production rates has encouraged the rocket engineers to invest in the relatively high-priced tooling necessary to produce high-pressure molded parts. The items currently fabricated in this manner are non-structural in nature, being used within the rocket as gas deflector shields, insulating boots and grain-support rings.

The use of high-pressure molding techniques for more components is limited because of the random nature of the reinforcement. If strengths were available in molded structures as required and as found in directed-laminated pieces, many additional items would be made in this manner. Currently studies on larger components are in progress, in which the direction of the reinforcement medium is being achieved by a hand lay-up pre-form, and the final strength and dimensions achieved by a concluding high-pressure cure. The use of molded, reinforced plastics in rocketry has a very prospective future. END

MISSILE PROBLEM

The incredibly long and expensive pathway of U. S. missile research and development since V-J Day has baffled and frustrated most lay observers. Missile complexity is the culprit in the delay and only a single example helps provide a clue to the time and money cost of the program. In preparation for the Matador project, the Glenn L. Martin Co. prepared a Republic F-84 Thunderjet by fixing its controls for pilotless flight. The fighter was launched by rocket booster with its own jet engine running while myriad instruments recorded data on its takeoff. Martin's conclusion: the stick-fixed stability of current jet fighters is wholly unsatisfactory for pilotless flight. This complex, expensive project was a necessary ingredient in the design development of the successful Matador.



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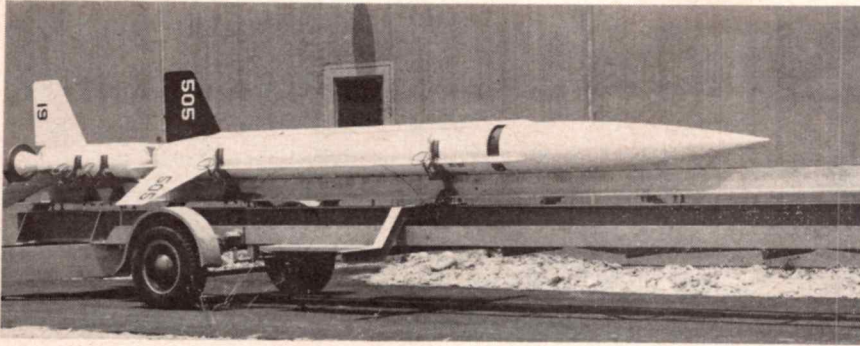
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The prospective use of such a material would appear to be unlimited. One rocket model alone, now in production, would use over 125 tons per month of reinforced plastic if the current chamber parts were made from such a material.

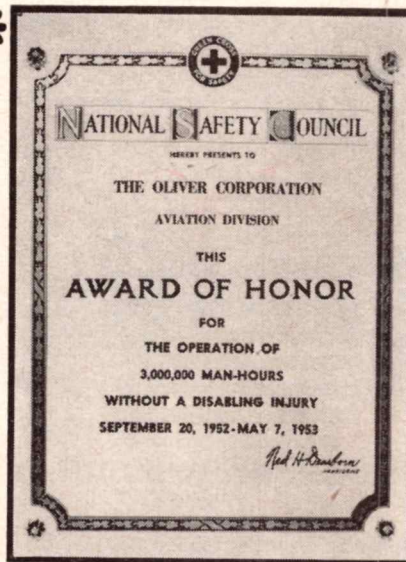
The particular property of low thermal conductivity of plastics has especial value in the field of rocketry. This property has led the guided missile motor or rocket designer to employ plastics as insulating media. The thermal conductivity of plastics is only a fraction of that of propellant or of structural metals. When it is considered that plastics weigh about one-third that of the usual metals used in the construction of rocket motors, it can readily be shown that considerable weight may be saved by using a plastic insulator for metal components.

Because of its high thermal conductivity, steel, for example, is rapidly heated to temperatures at which it loses much of its strength. By inserting a plastic sleeve insulator the steel part may be kept at a lower temperature where most of its strength is retained. Recent trends are towards guided missile motors of larger size and greater burning duration. Both of these conditions considerably aggravate the chamber-weight problem.

In the design of a recent, large, rocket-take-off motor, the use of a plastic insulating sleeve allowed the insulated chamber assembly to be approximately 70 percent of the weight of a similar design employing an uninsulated chamber. When it is shown that this represents a weight reduction of several hundred pounds on an airborne item, the importance of such a plastic application is apparent. A smaller rocket motor now going into production, will use an insulating boot of reinforced plastic. This application alone will require several tons of reinforced plastic per month. The use of plastic insulating materials in guided missile and rocket motors is certainly on the increase.

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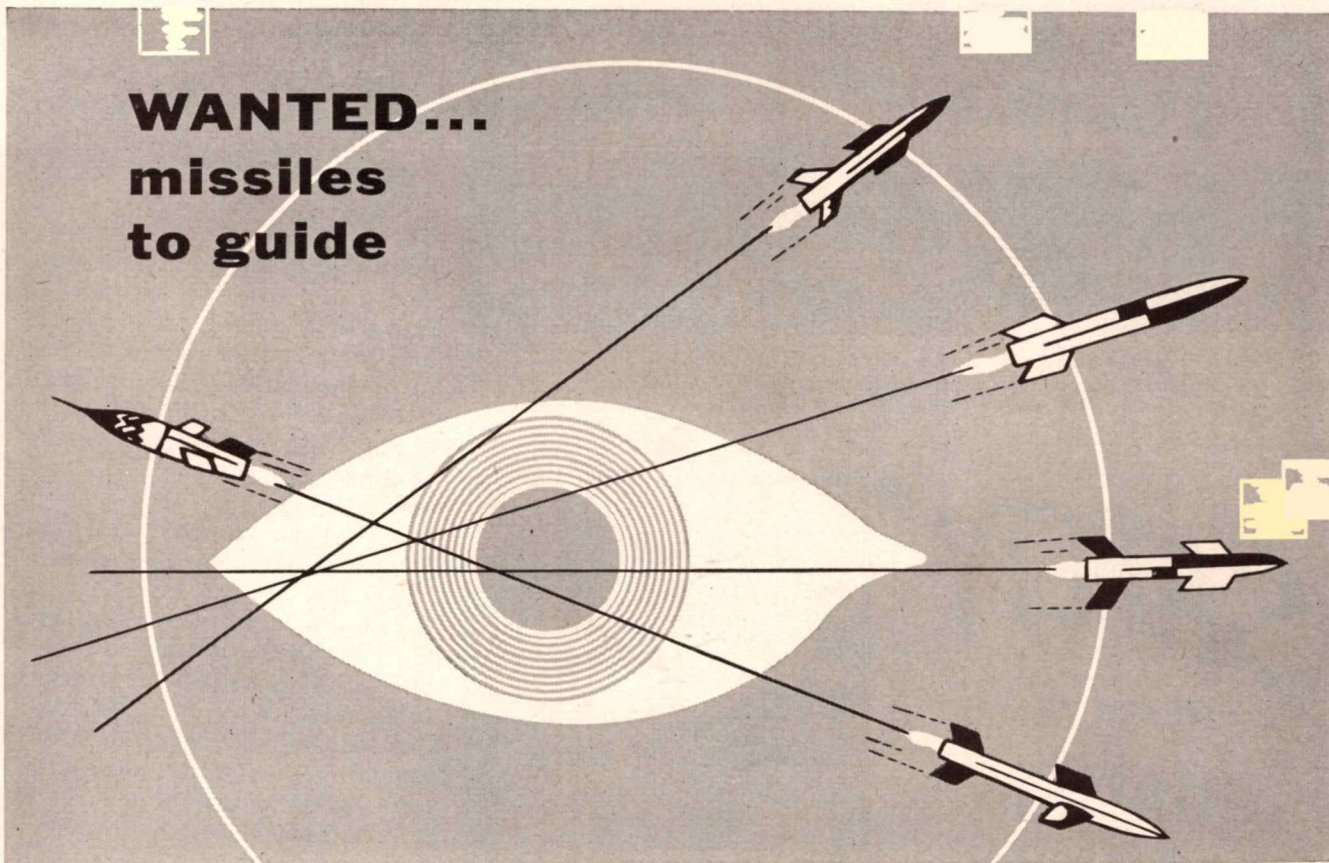
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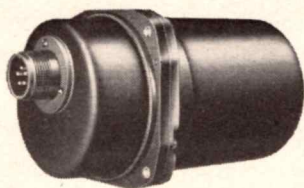
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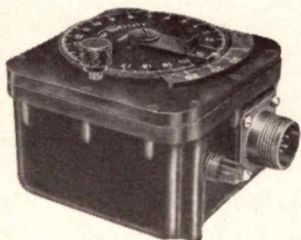
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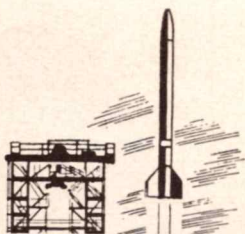
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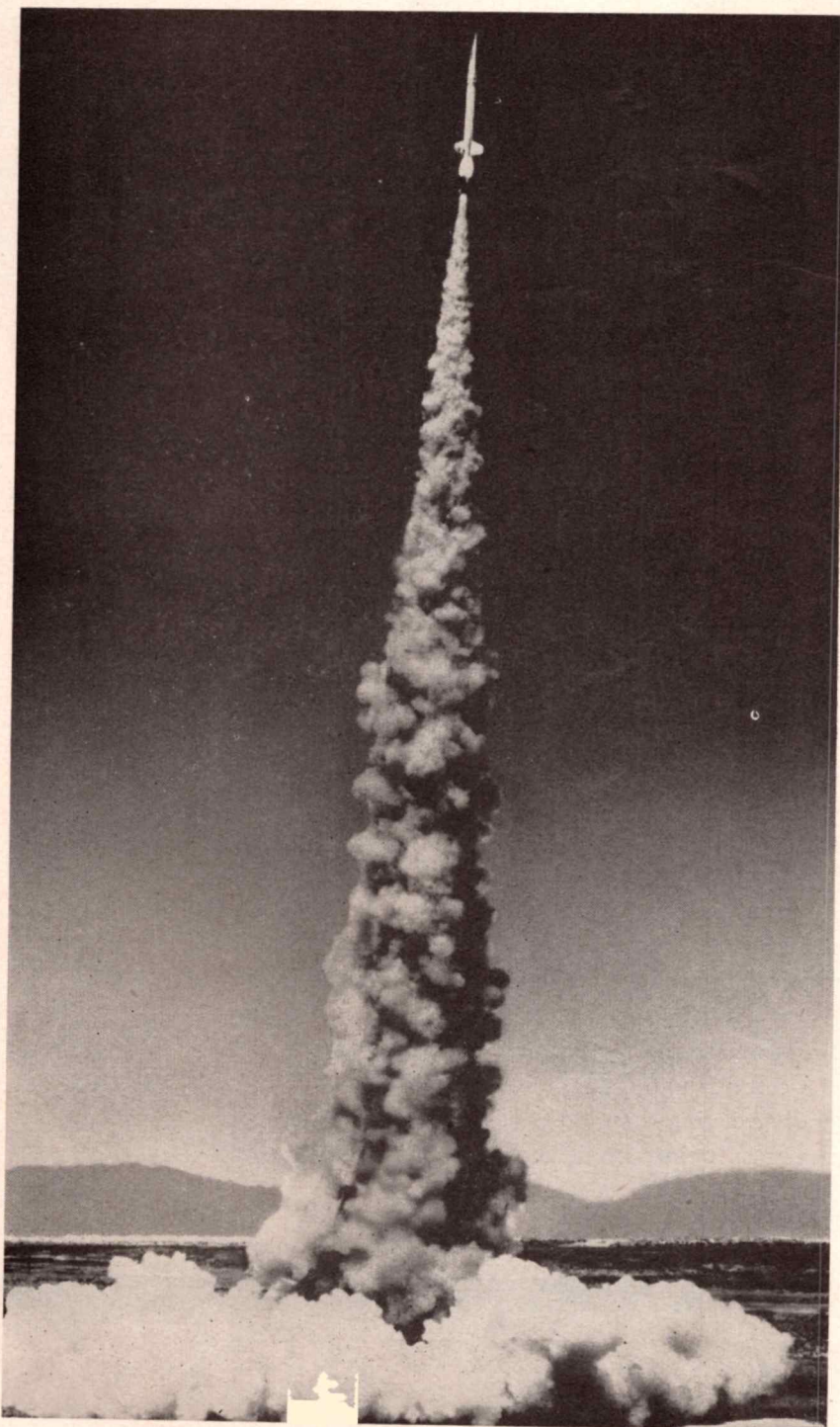


Plastics face expanding future
in rocket technology

missile materials

PLASTICS FUTURE

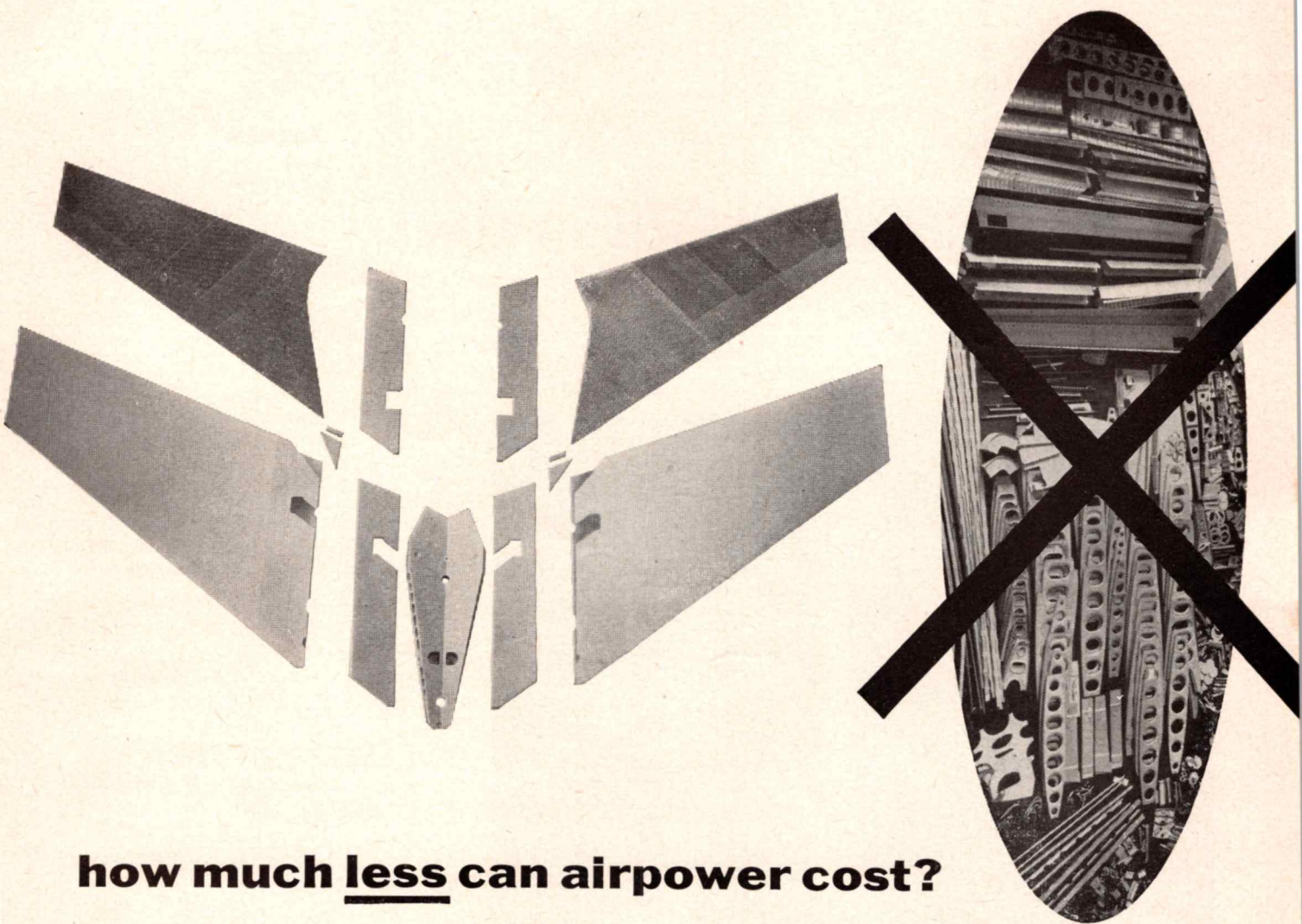
By MARVIN H. GOLD
Aerojet-General Corp.



THE greatest potential use for reinforced plastics is in the construction of the rocket chamber. This is the pressure vessel which contains the burning rocket propellant. The hot pressurized gases derived from the burning propellant leave the rocket chamber through the exit nozzle at the rear. This provides the forward acceleration to the rocket according to the laws of the conservation of momentum.

The main reason that reinforced plastics are not used for the purpose of rocket chamber construction lies in the limitation of the material itself. The reduction in weight that might be realized from the use of a plastic chamber, is as attractive to the rocket designer as it is to the aircraft designer. Aside from the high cost and the expensive fabrication techniques, both of which are, of course, of concern to the designer, the physical properties of the current reinforced plastics do not compare favorably with those of the metals now in use.

Because of the low initial tensile strength and the drop-off in strength with temperature, unusually heavy walls are required. This causes the plastic chamber to weigh nearly as much as the metal chambers. In addition, the Young's Modulus of the current reinforced materials is so low, that the containment of end-closures to maintain the pressure within the chamber is a major problem. Furthermore current reinforced plastics are often porous at pressures above 200 psi. A reinforced plastic that could be made to the following specifications would be eagerly sought and bought by the rocket designer:



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The stabilizer of the Matador consists of 13 parts. Shown beside it are some of the more than 3,000 parts which would be required to produce the stabilizer for a multi-engine transport by traditional methods.

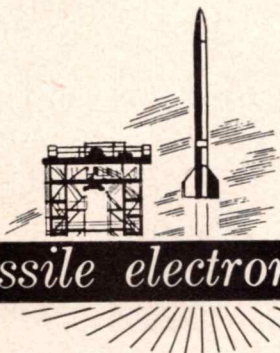
What of the Matador itself? New Martin processes and methods are producing this major weapons system for a fraction of the cost-per-pound of equivalent piloted aircraft—and to performance specifications more exacting than most.

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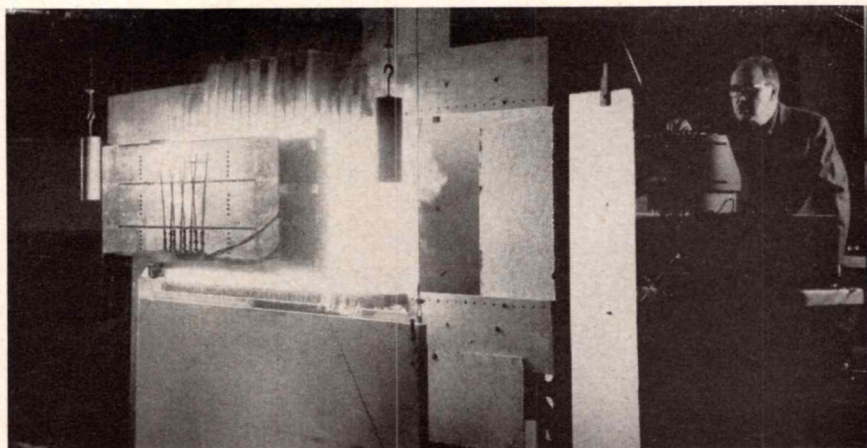




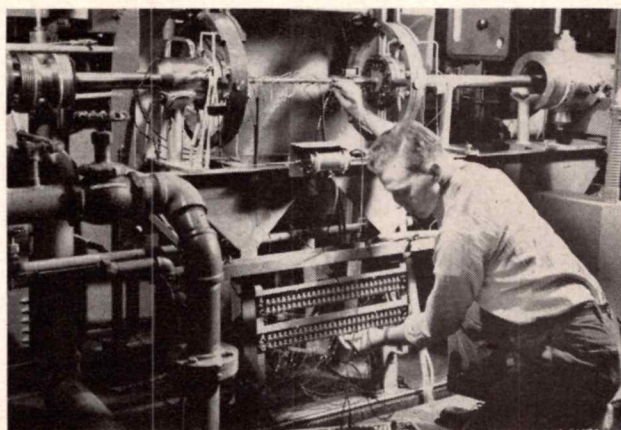
NACA PIONEERS MISSILE RESEARCH DATA

THE guided missile—its exterior form, its control surfaces, its powerplant—has its birth in the laboratories of the National Advisory Committee for Aeronautics. This birth takes place five, ten—even 15 years before the missile is fired for it is the task of the NACA to establish scientific principles upon which missile design is based.

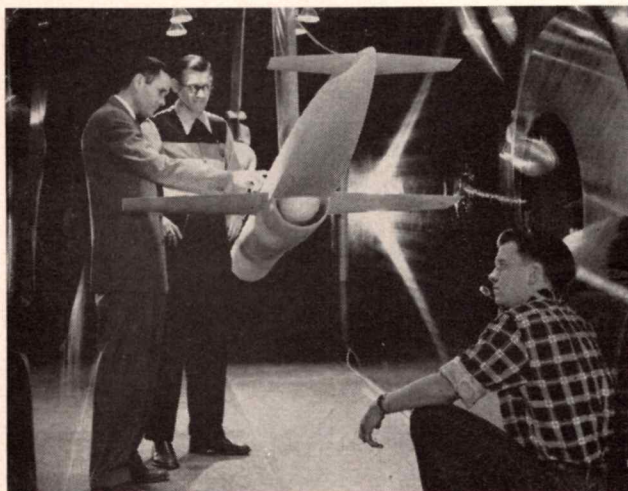
Propulsion principles, essential to missile performance, have their birthplace at the NACA Lewis Flight Propulsion Laboratory, Cleveland, Ohio. This fabulous house of miracles was host to official visitors last month and these pictures illustrate the complexity of those miracles. Yet here is the heart of the guided missile of 1960 in the act of its creation in 1954. This act combines the basic ingredients of theory and test in widely-varying proportions—but the two are inseparable in scientific missile progress. END



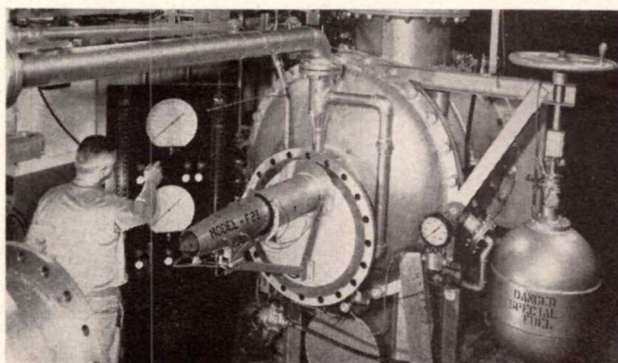
Missile skin friction heating is simulated by an array of incandescent carbon rods adjacent to a segment of wing structure



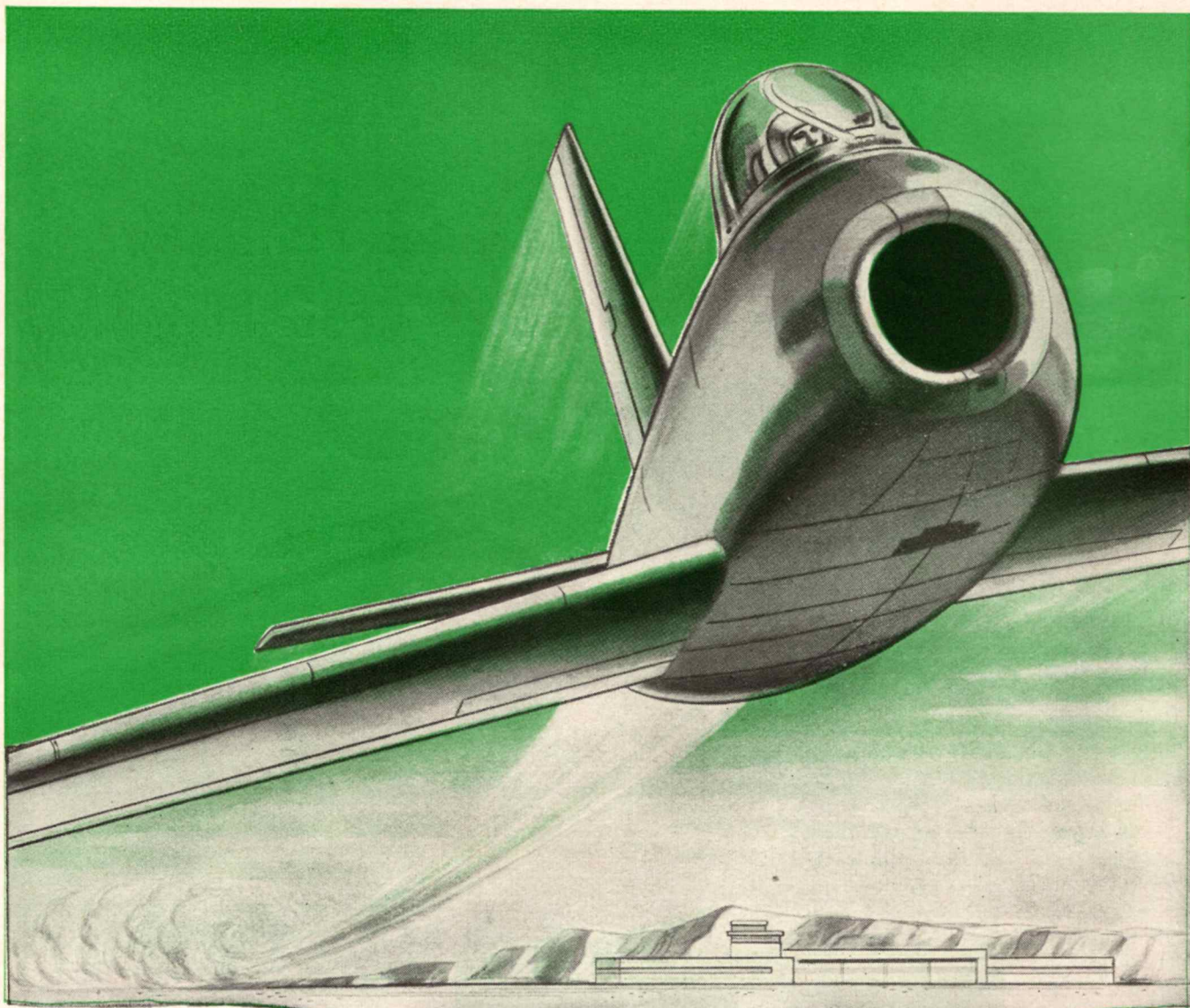
Heat transfer data is obtained in this temperature measuring apparatus, which supplies 1200 deg. F and 3000 psi pressures



One-quarter scale ramjet-powered missile is wind tunnel tested to simulated 1300 mph speed at 50,000 ft.



Model ramjet engine (center) is operated at simulated high altitude conditions after chamber (lower left) is bolted closed to tank at right



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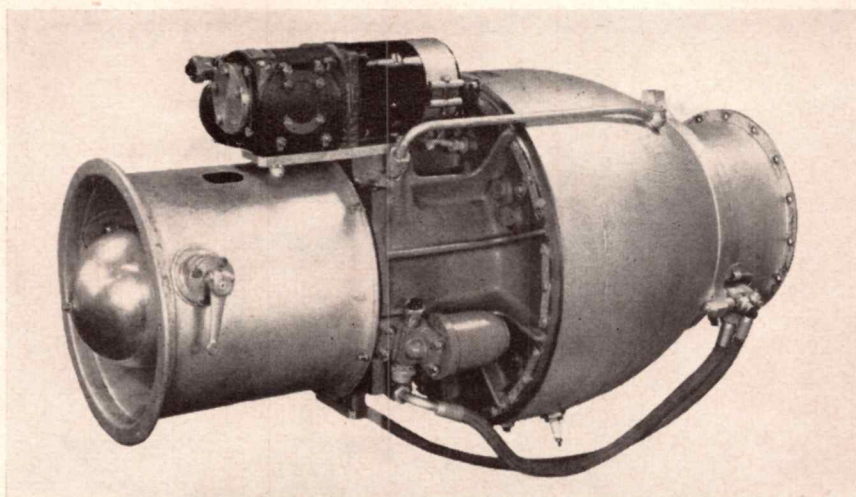
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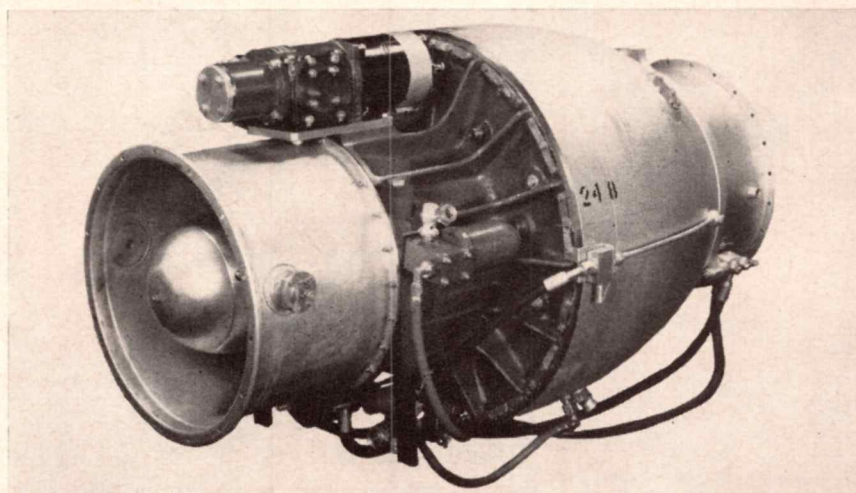
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Continental Palas turbojet delivers 330 lb. thrust yet weighs only 162 lb.

Continental J69 turbojet is in production for new version of Ryan Firebee target drone



missile propulsion

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Both of these turbojet engines have been developed as small, compact, light-weight, low fuel con-

sumption power plants. Both were developed with specific emphasis on low cost, high efficiency and dependability.

The larger of the two engines is the J 69 which delivers 1000 lb. of thrust, has a specific fuel consumption of 1.2, and weighs 304 lb. The combustor outer housing is 22 in. in diameter, and the engine length is 43 in.

The Palas generates 330 lb. of thrust at a specific fuel consumption of 1.16 and weighs 162 lb.—including the starter. Its small size is indicated by the 17 in. com-

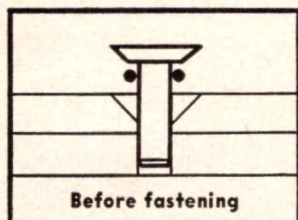
bustor diameter and an overall length of 36 in. excluding tailpipe.

In both of these engines, air enters the engine inlet at the forward end where it is compressed by a single-stage centrifugal compressor with radial and axial diffuser blades. The annular combustor with the fuel injected from a whirling shaft is a unique feature of both engines. The hot gases flow through the aircooled nozzle vanes, through the single-stage turbine, and then through the tailpipe jet nozzle.

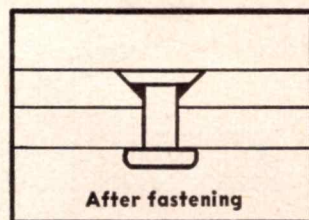
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pellant rocket propulsion should be noted. The first of these concerns the relation of the liquid propellant guided missile powerplant to the liquid propellant *piloted* aircraft powerplant.

The two types of application—missile and piloted aircraft—often involve several basically different requirements. These differences relate primarily to the categories of safety, reliability, serviceability and producibility. Without going into the details of these divisions, it can be understood that trends in these categories which are appropriate to a guided missile will frequently be inappropriate for a piloted aircraft powerplant and vice versa. Because nearly all liquid propellant rocket companies develop powerplants for both uses (and since the Navy and Air Force procure for both uses) it has not always been easy to keep these cross-currents separate in the proper cases. This problem has now been recognized and the trend is toward a clearer distinction between the requirements for the two uses when appropriate.

A second general trend is the recognition of the necessity for carrying on both short-term and long-term research and development programs on liquid propellant rocket systems and components. For some time, and properly so, considerable emphasis had been placed on getting powerplants developed, produced and operationally tested in minimum

time. This emphasis required a telescoping of production into development and of field trials into production. This had one desirable result, namely that we have operationally proven units at hand. It also had one undesirable result—in forcing the developer to design for producibility at the time when his hands were full in designing for function, both function and producibility were usually impaired.

It has become clear that producibility in a missile rocket powerplant or engine is achieved primarily through simplicity; and the achievement of simplicity frequently may involve designs which are unconservative—that is, system and/or component designs and design philosophies which depart more or less radically from previous background. To take this kind of gamble on a tightly scheduled development production-operation program can seldom be justified. Hence, there is definite need for longer term rocket powerplant development programs having as a goal greater simplicity as well as improved reliability.

A third general trend, related in a way to the second, and viewed with some concern by the rocket powerplant industry, is the tendency toward conducting the longer term development programs in perhaps too rigid a fashion specification-wise and with emphasis perhaps too early on

specific results. The mechanisms of injection, mixing and burning in a rocket chamber are most complex. Therefore, they warrant long term research. Yet at the same time it is advisable occasionally to strike out empirically yet intelligently, toward technical advancements through longer-term basic development with the minimum of service specifications and fiscal controls.

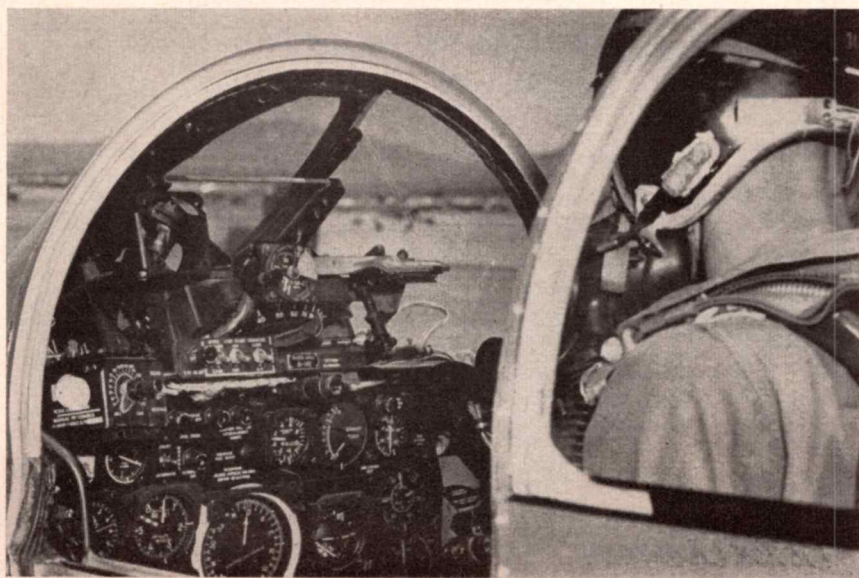
The classical example of what can be achieved with this approach in the rocket field is Dr. Goddard's first successful liquid rocket, fired in New Mexico in 1938. As we look at this historic relic in the museum of the Institute of Aeronautical Sciences and reflect that it was achieved by a handful of men with initiative and enthusiasm, we can have hope that there is still much to be accomplished in the rocket powerplant art by straight if advanced thinkers, and that there may always be a requirement and place for pioneers.

In conclusion, it may be stated as an axiom in the field of aviation that the greater the requirements for flight operation in terms of speed, altitude and range, the higher become the costs of research and development in dollar magnitude to attain these objectives.

Some statistically-minded mathematician might well empirically investigate the factual development backgrounds of the aircraft piston engine and gas turbines and come up with an exponential relationship between Mach numbers, range and development dollars which would be useful in impressing our military planners and budget directors that rocket powerplant development falls in the same pattern and costly category.

After all, the rocket powerplant is also a complex and high performance unit for specialized applications fulfilling a need supplied by no other type of powerplant. The same philosophy of design, research, development and production techniques painfully acquired over the years in the aircraft piston engine and gas turbine fields applies to the rocket.

First photo of secret Sperry A-4 radar-aimed, automatically-controlled gunsight in jet fighter cockpit. Gunsight won repeatedly in all-jet gunnery meet at Nellis AFB, Nev.



and pumping, flow control, injection, ignition, and combustion, among others. Numerous ways of accomplishing these functions have been and are being evolved. The combination used in a powerplant for a given application is of course dictated by the nature of the application and the state of the art. In general, the primary simplicity for small missiles and trend is toward systems of greater systems of greater reliability for large missiles. In smaller missiles and in violently maneuvering missiles the liquid propellant rocket powerplant will usually run second to a solid propellant rocket, primarily on the basis of relative complexity. The turbo-pump type of feed system, as used in the V-2, is favored over gas pressurized systems because it more than pays for its complexity in terms of reduced missile size and cost.

Thrust Chambers

The trend in thrust chambers is toward the ceramic-lined type for lower thrust and toward the regeneratively or self-cooled type for higher thrusts; in the regeneratively-cooled type primary emphasis is on the improvement of fabrication methods. The question of single versus multiple chambers for larger thrust is receiving continued attention, the primary factors being relative weights, development costs, development times, production costs, and reliabilities. Use of elements of the powerplant to assist in missile control has been well advanced over the V-2, the most striking example of this technique being the Navy's record-breaking *Viking* sounding rocket built by The Glenn L. Martin Company and powered by a Reaction Motors, Inc. engine. Interest in variable thrust liquid rocket systems continues, although for many applications it appears at present simpler to hold powerplant thrust constant and to take care of speed variations by control system changes than to complicate the powerplant itself.

Certain general trends and needs in the field of liquid pro-

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required to meet the mass production demand. New and promising approaches to this problem have been undertaken, although it does appear that for some time to come significantly lower propellant costs (apart from those resulting from proposed mass production techniques) will involve some sacrifice in propellant performance. Associated with the development of improved propellants is the improvement of reproducibility of

propellant composition and physical homogeneity of the grain. Methods of inspection of grains are being continually improved in order to insure high reliability.

Solid propellant rocket motor cases have been the subject of considerable research and development effort, primarily in the direction of lower weight, higher producibility, and lower requirements for strategic materials. Remarkable improvements have been

achieved through a number of combinations of materials and design.

The above trends in solid propellant rocket propulsion for guided missiles have been closely intermingled with, and are in some cases identical with, trends in solid propellant rocket propulsion for unguided missile and piloted aircraft applications.

Liquid Propellant Rockets

Whereas the solid propellant rocket unit has only two primary elements, namely the propellant grain and the case, liquid propellant rocket missile powerplants can take many different basic forms and may operate on any of numerous propellant combinations.

Within the field of guided missile rocket powerplants, a wide variety of specific applications exists within the general framework of surface/surface, surface/air, air/surface and air/air applications (with further breakdowns based on missile range). This fact has dictated a number of different types of liquid powerplant designs. Hence, a brief review of technical trends in this field can only touch on the points of possible general interest.

Liquid Propellants

Propellant trends have been dictated primarily by the balance between storability, availability, performance and freezing point for each application considered. In general, among the oxidizers, nitric acid is currently preferred for the smaller or the "ever-ready" missiles and liquid oxygen for the larger, V-2 type missiles. Hydrogen peroxide, because of cost and high freezing point, appears to have more limited use. Among the fuels, alcohol, ammonia, gasoline, hydrazine and jet fuel appear to cover most applications. There is now a most salutary trend toward standardization of rocket propellants in terms of basic types and specific compositions.

Systems and Components

Many functions must be performed in a liquid propellant rocket powerplant system—propellant storage, propellant feeding



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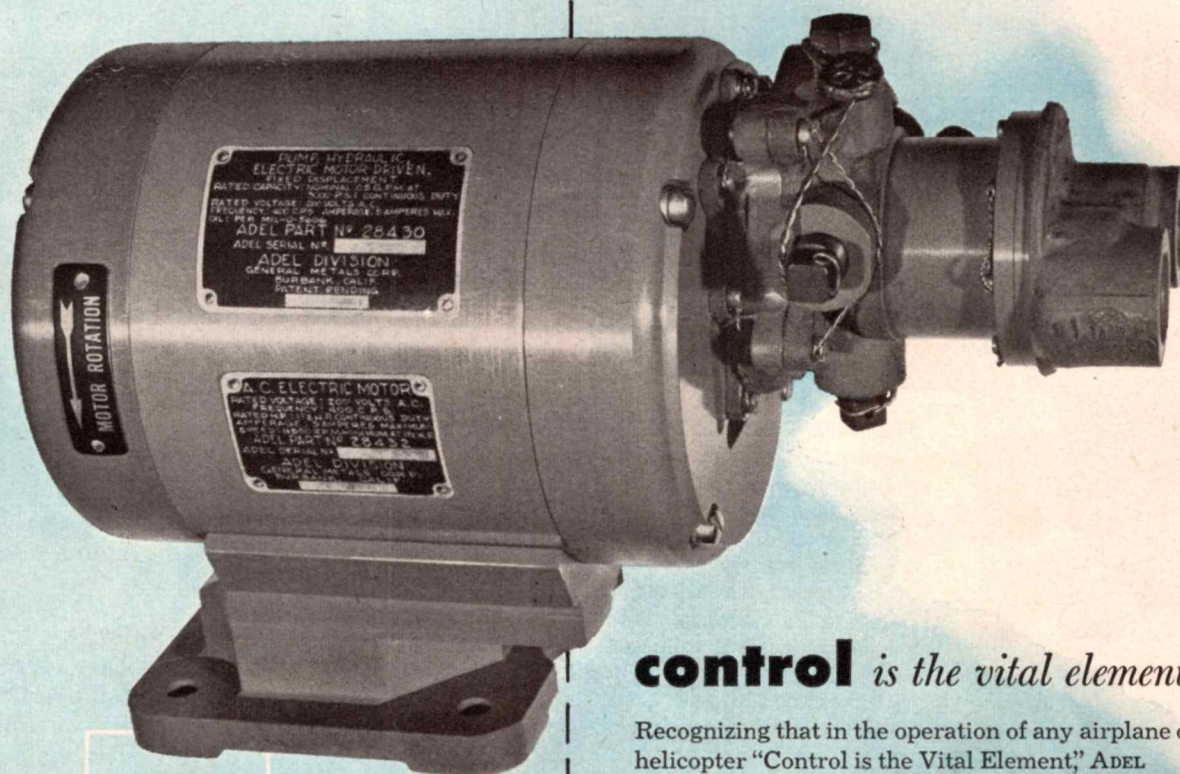
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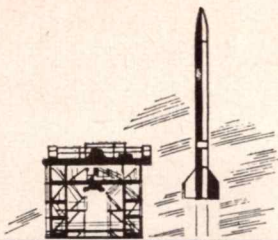
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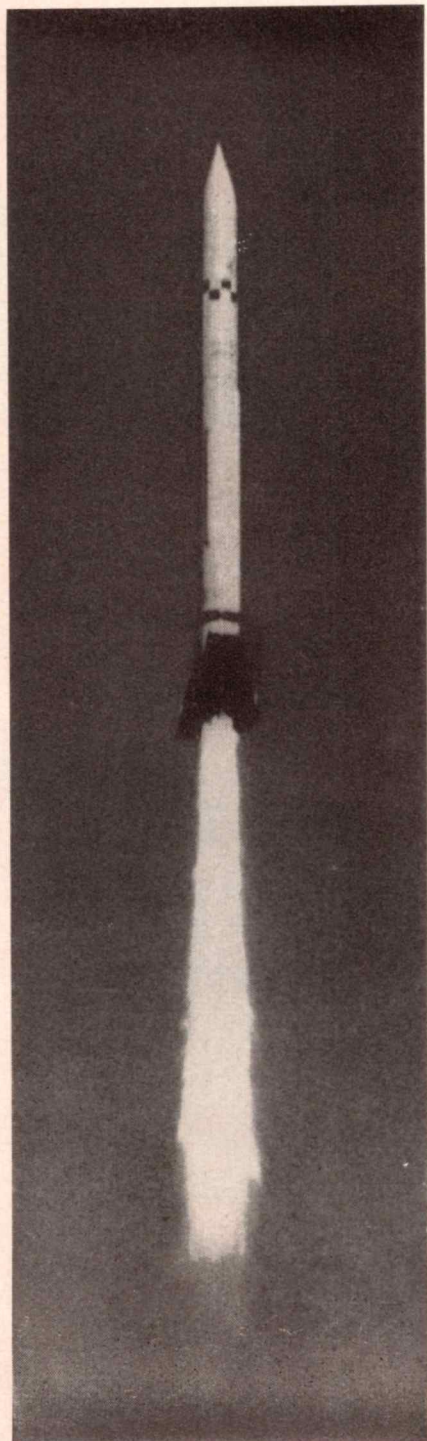


missile propulsion

PROGRESS IN ROCKET FUELS

By **RAYMOND W. YOUNG**

President, Reaction Motors, Inc.



TEN years ago the falling of the first German V-2's on London awakened the world to the full potentiality of the rocket powered guided missile. Most rudely awakened perhaps (apart from the Londoner) was the American technical man-in-the-street. Here, developed, produced in quantity, and being used tactically, was a powerplant not only new to most of us, but huge even to those who were aware of rocket power. The idea of a 28-ton thrust turbo-pump-fed rocket was like the idea of an atomic bomb—something from the world of Buck Rogers. For ten years now we have been very much in that world. What have been our general technical trends during this period and in the field of missile rocket propulsion? How can they be interpreted?

The basic trend in the field of rocket propulsion for missiles has been one of expansion; first in trained rocket scientists and rocket engineers; more recently in military budgets, and in facilities, both military and industrial. This expansion has been motivated, of course, by the inherent ability of the rocket powerplant, in all of its numerous forms, to propel missiles at high speeds and altitudes; and by the military necessity for ultra-high speeds in any future war. This military requirement for speed is much more urgent today than it was during

World War II. Future attacks will be made by near-sonic and supersonic enemy aircraft; defenses against these craft must now be provided around our own cities as well as in our aircraft, naval vessels, and military installations; and last we must, in this nuclear age, be able also to retaliate instantly at long range in the event of an all-out attack upon us.

Within this basic trend of expansion are a number of technical-military trends in research and development on solid propellant and liquid propellant powerplants.

Solid Propellant Rockets

Over the past ten years many of the early problems of physical grain properties, temperature limitations, ignition, burning rate characteristics, and reliability in rocket solid propellants have been overcome or greatly reduced.

Major contributors in this effort have been such agencies as the Aerojet-General Corporation, Hercules' Allegany Ballistics Laboratory, California Institute of Technology's Jet Propulsion Laboratory, Thiokol Corporation, and other agencies. Solid propellant performance (specific impulse) has been improved and further improvements can be expected.

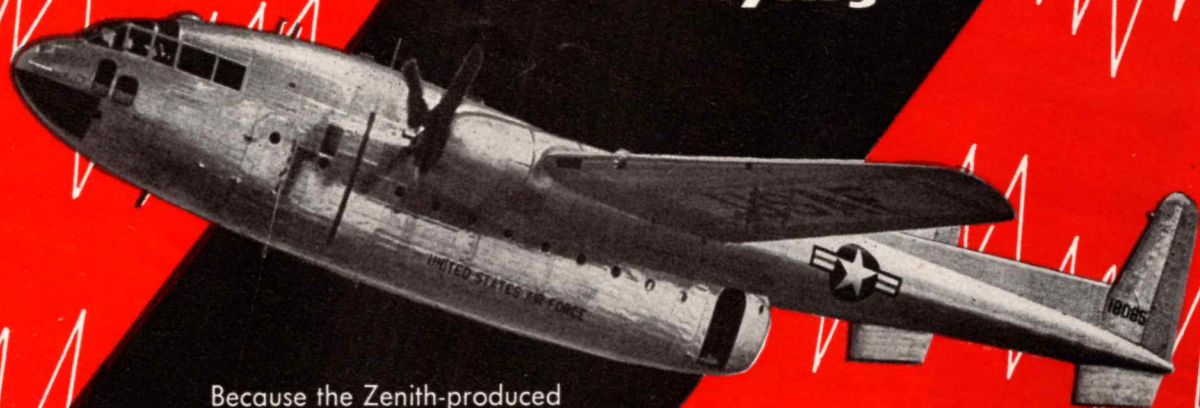
A primary problem not yet fully solved is the dual problem of high propellant cost and the high cost of the manufacturing facilities

Famed expert gives views on trends in rocket propulsion for guided missiles

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enemy devices attempt to blind it, deceive it, and confuse it. If it cannot do this, the entire missile cannot normally be sent into battle.

All this is made even more significant by the fact that the guidance system functions are carried out by products of the newer electronic sciences, such as radar and computing devices. This results in unexpected difficulties that often crop up to plague the designers, but it also gives almost unlimited opportunity for application of ingenuity and skill in conquering these difficulties.

From a consideration of all these factors it is not hard to understand why guidance has proved a difficult field to conquer, and why it has demanded a major application of effort. Indeed, in view of the above, it would seem strange if it were otherwise.

Yet, this is not the end of it. For even when a basically sound system has been conceived, inherently capable of meeting all requirements, the normal testing which is a part of any system development must be carried out under difficult conditions. For example, at the end of the flight test in a missile, the equipment being tested is completely destroyed—it cannot be watched over while undergoing test operation in its intended environment (except via telemetering), and it cannot be examined after the test to determine the cause of any unexpected behavior, nor can it be adjusted and tested again. The equipment environment itself is relatively little understood, since it has never been observed directly, but deduced

from analogy to aircraft environment and from data relayed via telemetering.

Furthermore, with the equipment at hand, the achievement of satisfactory reliability of this complex and sensitive equipment under these conditions has been difficult to attain. Each set of truly valid data must be obtained in a brief period of flight, at a considerable effort, with the expenditure of an expensive missile. Laboratory tests of the kind which contributes to substantial reliability have often been meager by comparison with that used for even a simple system in the automobile industry, for example. The demands on the engineers carrying out the work in this new and complex field are such that they cannot normally be expected to be experts in reliability as well.

In spite of all these things, the guidance problems are gradually being licked. New methods are being implemented to meet the situation as they find it, as the engineers charged with the responsibility for developing these systems doggedly pursue their tasks, undismayed by whatever difficulties with which they have been confronted. The problems are yielding to their steady onslaught—suitable systems are beginning to emerge which meet all the requirements and conditions discussed above.

This has been the result of several things, in addition to the dogged persistence of the engineers. For one thing, it has only relatively recently been fully and widely appreciated what methods and techniques are required to adequately achieve the required reli-

ability. For example, it has become widely appreciated that more than ordinarily high reliability is required of each and every one of the thousands of components in these complex systems, and that the required degree of reliability must apply with the components operating under the exact conditions present as they are being used in these systems.

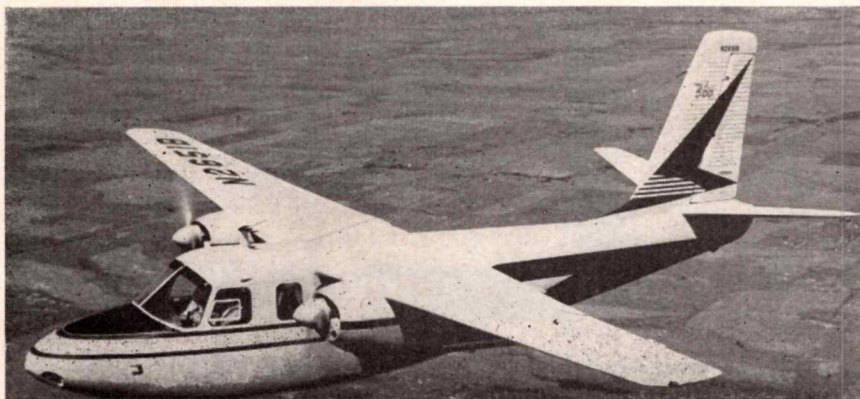
Relays Unreliable

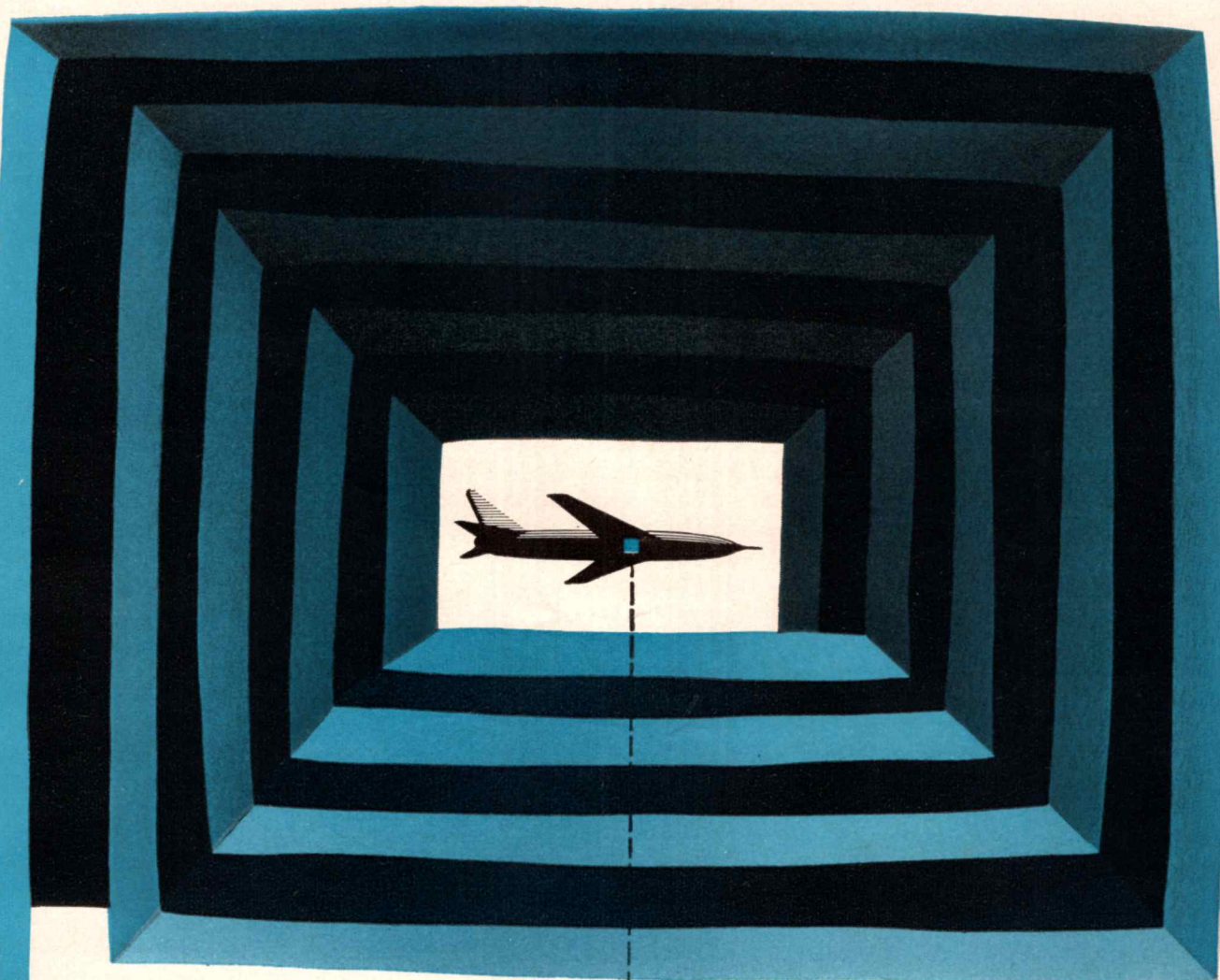
Telephone relays, for example, which are near the ultimate in reliability in their intended application, were found to be quite unreliable in a missile environment. Another concept which has emerged is that the complete systems must be capable of a large number of completely automatic successive perfect performances under the rigors of fully simulated missile flight operating conditions, in order to possess sufficient inherent reliability to give reasonable assurance of successful operation during the actual missile flight. This is in contrast to the original "short life" concept held earlier for missile system design requirements, and there have been many others. Some of these things seem quite obvious as viewed in retrospect. Others are considerably more subtle.

Today, a sufficient number of different guidance systems using various principles have been shaken down, and a sufficient backlog of experience with them and their associated development history such that the whole problem of guidance system development is becoming much better understood, and is becoming a little more a science, and a little less an art. So, today, the guidance development engineer can occasionally look up from the complexities of a system under consideration, and take time also to carefully consider the other elements, rather than encounter them later on when dealing with them may be more difficult.

Yet development of guidance systems probably will never be easy, for these systems are not simple, and probably never will be, because the nature of their function is inherently complex. END

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inference gains full prominence, for it permeates every aspect, including trouble-shooting, testing, and many others, in addition to those listed above. Not only must the available attention to detail be shared among all the component parts of the devices required to accommodate this complexity, but also the number of parts geometrically increases the required functional perfection required of each. These two factors, as we should certainly expect, have conspired to greatly impede our efforts to develop satisfactorily operating guidance systems.

New Equipment

The novelty of the functions required (and consequently of the equipment for implementing them) has contributed its share to guidance system difficulties, for it means that new equipment must be developed for most of the system, and available equipment must be used in new ways. This means that each system is an accumulation of untried, untested, and unproven equipment brought together in an unprecedented arrangement. Small wonder it is that much difficulty is encountered under these circumstances.

Likewise, the fact that a more sophisticated, higher plane operation is involved also contributes a sizable share to the load of difficulties stacked against the guidance system development task. The guidance system must seek out and keep the target under observation, analyze resulting data continuously to determine relative position of the missile itself to the target, continuously compute or otherwise determine the desired path from that position to the target, and send the required corrective signal to the control system to accomplish this.

It must be capable of doing this correctly in spite of all sorts of distractions, such as multiple targets, camouflage, and jamming. It must be capable of effective operation despite any countermeasures the enemy can reasonably be expected to use against it. This becomes a battle of wits. The guidance system must guide the missile unerringly to the target, while the



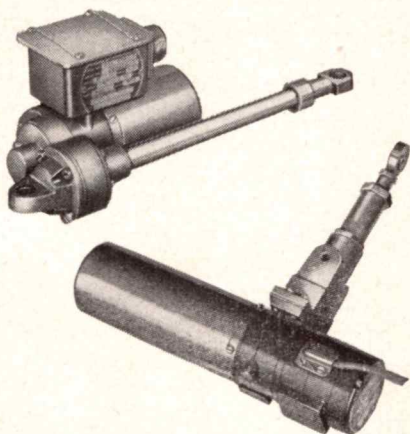
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conceived device that really works is a more formidable adversary than another human operator with comparable equipment that can be met on even terms. Yet the human operator may be able to win over a mechanical foe by ingenuity and extensive reserve capacities, including analysis, judgment, inventiveness and trickery. A human operator must be trained, the electro-mechanical substitute must be developed.

In accordance with our definition, we see that the automatic control system functions correspond to muscle functions, coordination, orientation and stabilization sensing of the human operator; and that they are essentially those of the autopilot, which has been functioning in routine aircraft applications for over two decades.

Brain Compared

The automatic guidance system function corresponds to the human operator's brain and higher senses and has no such backlog of experience, or previous extensive application. From this alone we should expect to encounter much greater amount of trouble with the guidance systems. For not only are they a relatively new type of equipment, which always gives more trouble, but they are inherently more complex and sensitive for they carry out more complex and sophisticated functions; and complexity and development difficulty go hand in hand.

In focusing our attention on guidance systems, we can examine more closely the consequences of their general characteristics. We have seen that outstanding characteristics include: (1) inherent complexity (due to complexity of their functions); (2) novelty, both of the functional operations involved, and equipment required to carry them out; and (3) a more sophisticated, higher plane operation, with consequently more refined techniques and equipment required. Let us examine the effect of each of these more closely.

Complexity automatically infers increased development, design, fabrication, and operational difficulty. But in missile guidance systems this

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Damping Factor: Instruments up to ± 7.5 G's inclusive can be damped .4 to .6 critical; ± 7.5 G's to ± 10 G incl. .35 to .55 critical; above 10 G's .3 to .5 critical.

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Potentiometer Resistance: From 1000 to 10,000.

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Linearity: $\pm 0.5\%$ of best straight line through calibration points.

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Crosstalk error: Less than 1% change caused by lateral acceleration equivalent to total range of instrument.

Weight: 2 to 2 1/4 lbs., depending on "G" range.

Overall Physical Size: 3 1/4" x 3 1/8" x 2 5/8".

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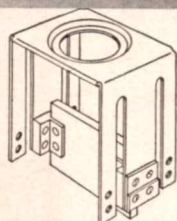
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siles were simply a mass or explosive propelled toward, or dropped upon, their target, reaching their ultimate development as projectiles fired from guns, or bombs dropped from aircraft. Propulsion, airframe, and control devices were added, and then guidance. The amount of experience behind each of these elements decreases in the order given, with guidance having the least in the evolutionary process; and, second, we note a characteristic increasing complexity in the same direction, the guidance element being in the ultimate position.

Control and Guidance

Let's take a closer look at guidance system characteristics, to get at the heart of the problem. Fundamental to the principle of the guided missile is that we substitute electro-mechanical devices for carrying out functions that in similar machines are carried out by a human operator. These functions are essentially control and guidance.

The control system (or autopilot) is that system which will cause the missile to fly steadily in a straight line, and will respond to and execute an input command signal directing it to deviate by a desired amount.

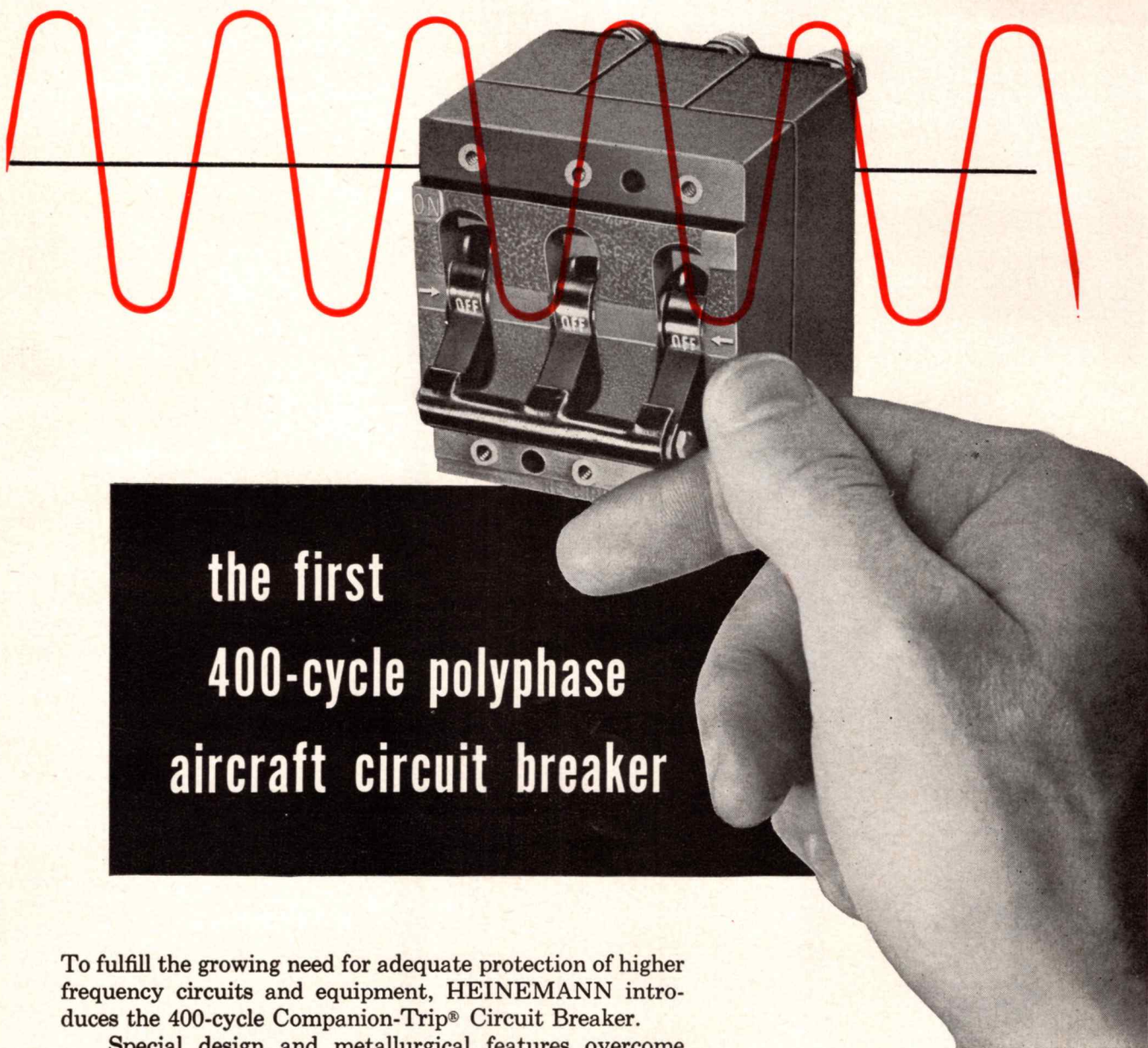
The guidance system is that system which (by its output signal) directs the control system to execute a desired change in direction.

A number of advantages are afforded by using electro-mechanical devices instead of a human operator. Significant among these are that they are expendable, and unemotional. Also, they are capable of much faster operation than a human operator, and can be specifically tailored to do a particular job, rather than adapted to it.

But there are disadvantages, too. The devices must be developed, which includes overcoming the difficulties in achieving satisfactory reliability. Further, they lack the automatic flexibility, or ability to adjust their operation to fit new and unforeseen conditions as can a human operator. Ingenuity and inventiveness are not among their talents.

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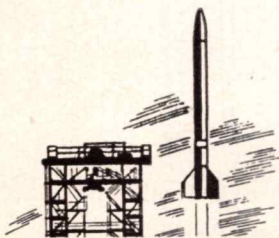
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missile electronics

Incredible difficulty of the demands on a missile guidance system are pointed up sharply by these two experts

GUIDANCE PROBLEMS

By DARRELL C. ROMICK

and H. F. LANIER

Aerophysics Department, Goodyear Aircraft Corp.

GUIDED missiles have been a long time in coming of age. When the program was launched in earnest, following World War II, most people close to it were visualizing four to five years for their development, but as the end of that period drew near there came a gradual, painful awakening to the realization that the goal was not even close—many wondered whether it was even in sight.

Today that goal is finally being realized, as one by one we see the first of the brood being paraded out and sent to their appointed tasks—the *Matador*, *Nike*, *Regulus*, and so on—although many more have not yet put in their appearance. Some, we hear, are undergoing their final grooming, in preparation for their debut. Those already out have yet to prove themselves on the job, but they are believed to be ready.

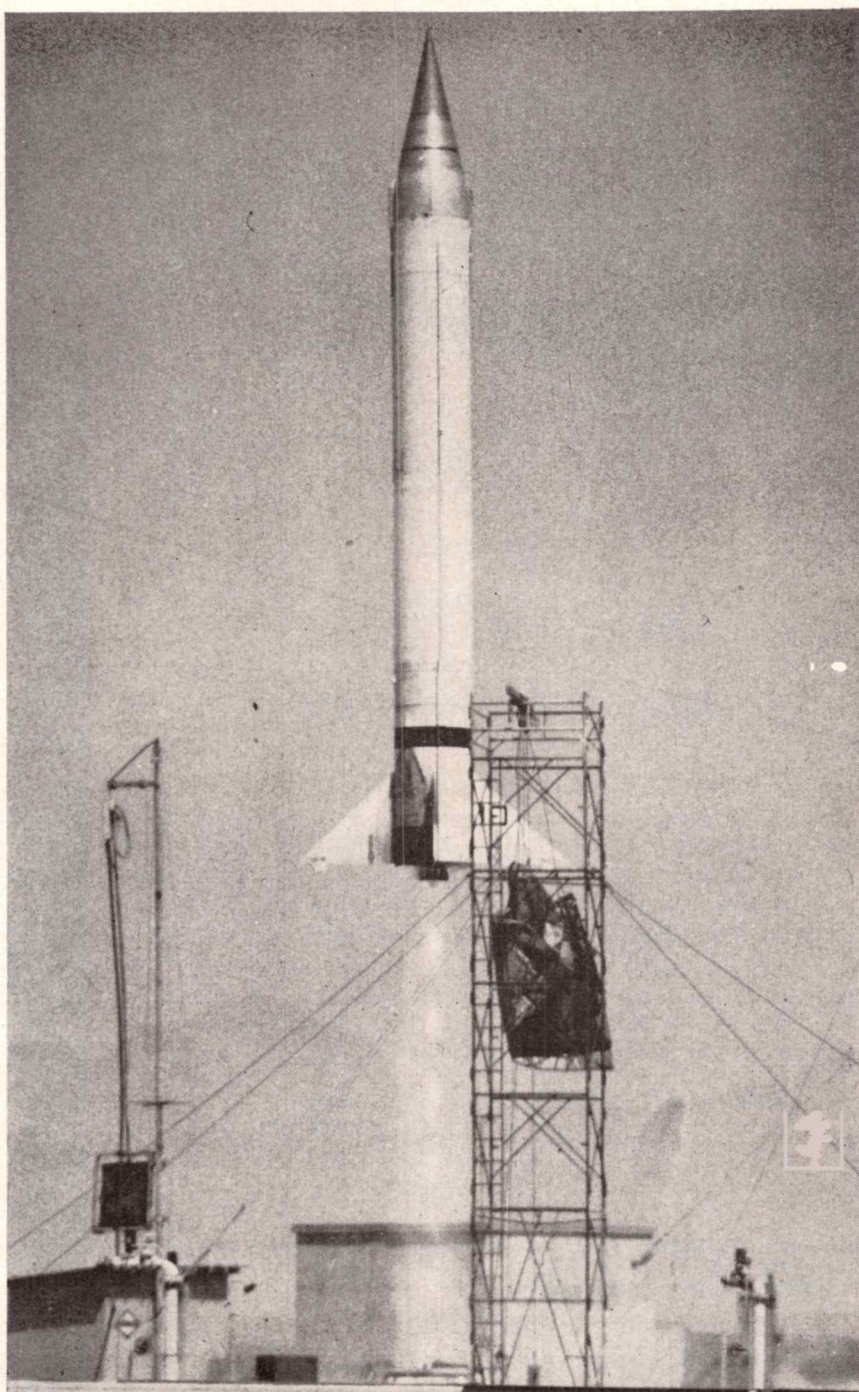
What has been the stumbling block that caused this halting start, and has made so unexpectedly difficult their development and preparation for duty at the battle stations?

Actually there have been many things, but none have been quite so pronounced as the problems of guidance, a major stumbling block.

Why is guidance so difficult?

This question is worth careful consideration—and we do not have to look far for answers.

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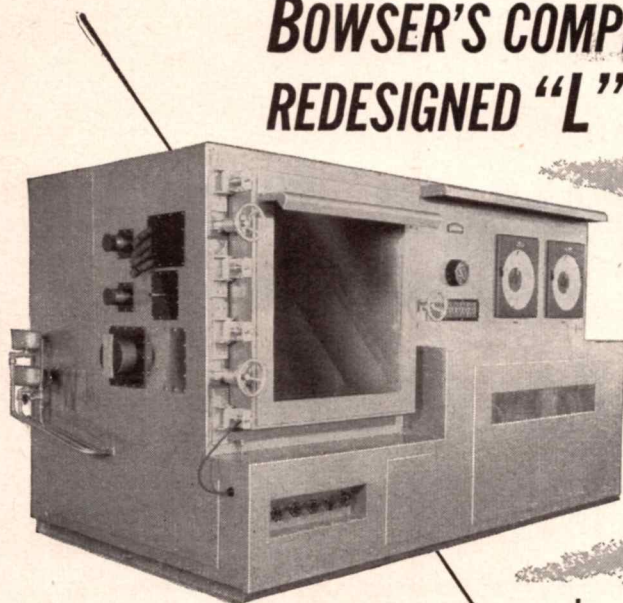
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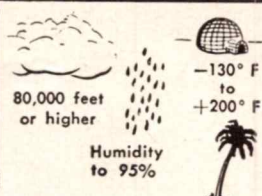
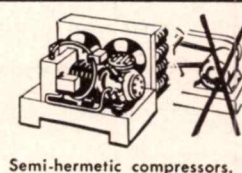
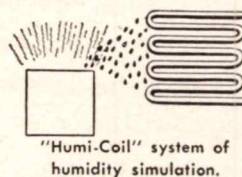


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materials. Along with them, we must also consider the problems of aerodynamic loading imposed by the combination of high-speed flight with high skin temperatures induced by that speed. As previously indicated, conventional organic resins begin to lose their strength somewhere in a range below 300 degrees F. Predictions of skin temperatures on missiles in supersonic flight indicate that 1,000 degrees F. may be expected, and higher temperatures are possible.

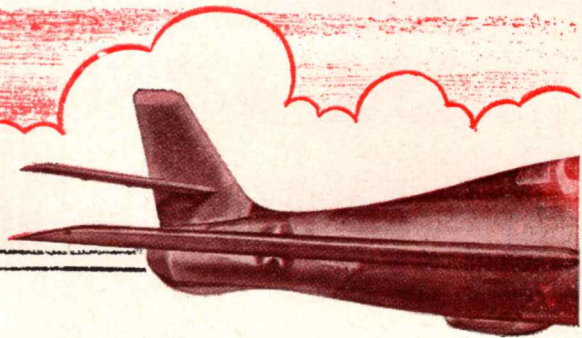
Development of acceptable materials for these temperature ranges must be coordinated with the design of navigation systems, in order that optimum use of these materials may be attained. The addition of chemical agents to organic resins has raised their temperature resistance somewhat without serious detriment to their electrical properties. New resins, based upon more stable compositions, also indicate promise. Low-dielectric glasses give indication of permitting greater wall thicknesses, while maintaining acceptable electrical transmission.

Close Coordination

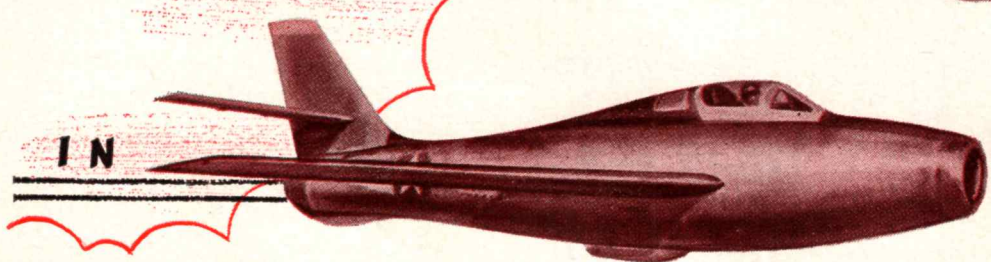
The area of passive navigation equipment is one that cannot be discussed without running into security barriers. However, generalizations may be made to the effect that similar problems exist in the fields of acoustics and heat to those in the electromagnetic ranges. Sensitive equipments require delicate handling and precision construction. Dimensional tolerances are dependent upon fabricating conditions initially and upon environmental conditions during operation. Unless close coordination is maintained, that which is completely acceptable at the time of manufacture will fail utterly when its most precise performance is needed.

Here, then, is the challenge for the materials and process engineer. It is up to him to devise, produce, and control materials that will meet the completely unbelievable specifications laid down by the scientists who are developing the systems that will determine our supremacy—or our failure—in the fight to preserve our way of life.

END

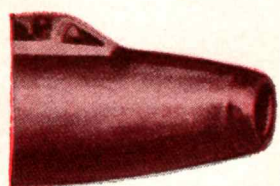


ON THE TAKE OFF



IN

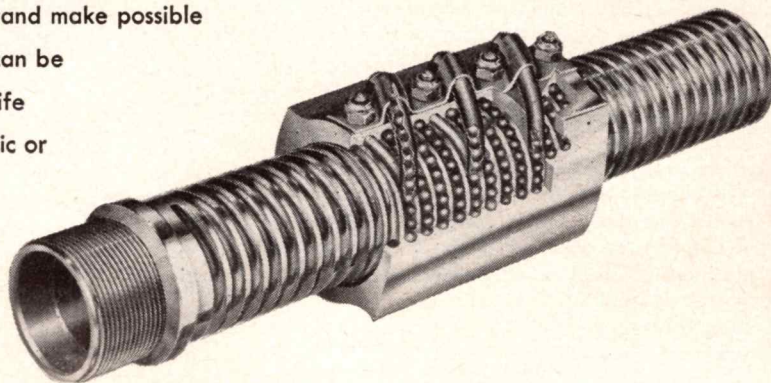
THE AIR



OR MAKING AN APPROACH

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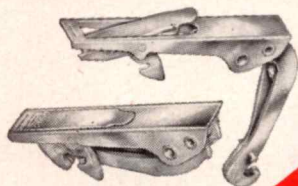
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which send out no radiations of their own, but depend rather upon the detection of heat or sound radiation from their targets to guide them upon their mission of destruction.

There are, of course, semi-active devices, too, but they have problems common to the active and the passive systems, so that a description of their theory of operation is not necessary.

What, then, are the materials problems of these systems that make it so difficult for their designers to keep pace with the rapid strides being taken in the propulsion field?

Dielectric Qualities

Primarily, the problems are dictated by the peculiarities of the electromagnetic spectrum. Considerable literature has been published on the theory of radome design. In summary, it boils down to the fact that microwave beams behave in a manner similar to light waves, in that they are transmitted, reflected, refracted, and absorbed by the media through which they must pass. The mathematics of their behavior is highly complex, but again it may be stated that the performance of the system is dependent upon the specific inductive capacity ("dielectric constant") of the medium, and upon its loss tangent.

The words "dielectric constant" have been deliberately enclosed in quotation marks, because there seems to be nothing that is less constant than a dielectric constant. This property of a material varies, usually with time, with temperature, with frequency of measurement, and, in some cases, with the intensity of the electromagnetic field in which it is measured.

Since the index of refraction is directly related to the square root of the dielectric constant, it is apparent that the accuracy of propagation of the microwave beam through a radome will depend upon the constancy of that so-called "constant." Too, the thickness of the radome enclosing the radiating system is a direct function of the dielectric constant. The higher the "constant," in general, the thinner must be the wall. Then, too, fluctuations or changes of dielectric

constant will result in concomitant variations in transmission and refraction of the radiated beam.

Here, then, we begin to see the problems which face the electronics men who attempt to provide reliable guidance equipments. Up to the present time, the greater portion of the research and development effort involved the design of accurate equipments for navigational or gun-laying systems for subsonic, transonic, and "slightly" supersonic aircraft.

The microwave beam behaves in precisely the same manner. As it passes through the interface between the air medium and the plastic housing (the dielectric medium), the beam experiences a slowing down, or "phase delay" of its wave front, so that it emerges along a line different from that along which it entered. The angle between the entering ray and the emergent ray is known as the shift angle, and is usually only a small fraction of a degree. However, since the target information supplied by the computer to the navigation system depends upon a knowledge of the precise antenna position at each moment, even the small deviation caused by the bore-sight shift is sufficient to cause inaccurate information to be fed to the computer. The consequence of this inaccuracy is usually a miss.

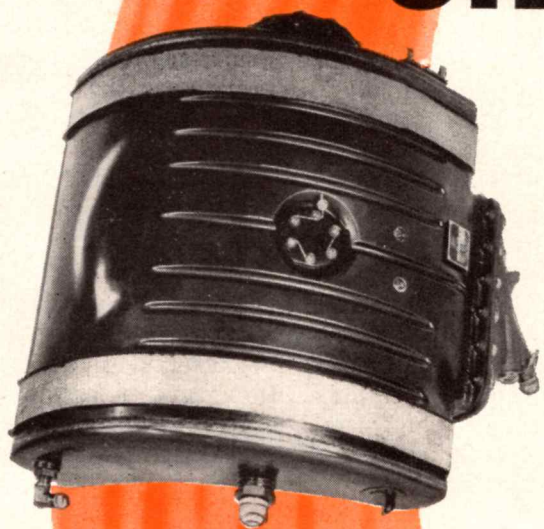
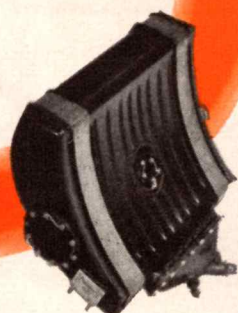
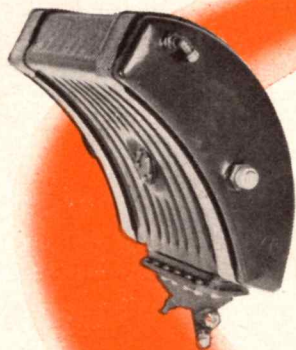
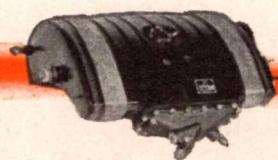
Variable Shift

If the dielectric constant of the plastic medium were really uniform over its entire area and over all ranges of temperature, it would be possible to insert a corrective circuit into the electronic system that would account for the shift and make proper compensation. However, such is not the case.

On the contrary, the variations in dielectric constant may be such as to cause the shift to vary from point to point over the radome. This change of shift, in turn, has a tendency to give inaccurate information as to target speed, so that again the navigation system makes a wrong decision.

These, of course, are only a few of the electronic problems associated with the dearth of acceptable

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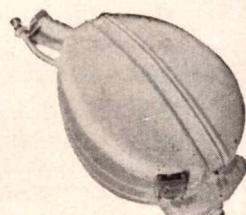
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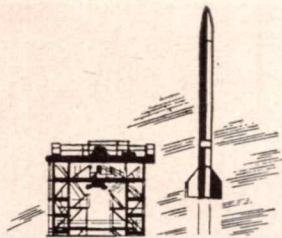


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New plastic materials and techniques offered for radome design

missile materials

ELECTROMAGNETIC PROBLEM

By SAMUEL S. OLEESKY
Chief Scientist, Micronics, Inc.

RECENT announcements in the press have disclosed that rockets and missiles have risen more than 150 miles from the earth's surface, at speeds exceeding 4,000 mph. While these figures seem almost unbelievable to the layman, they have long been expected, and feared, by those engaged in the design and development of weapons and guided missiles.

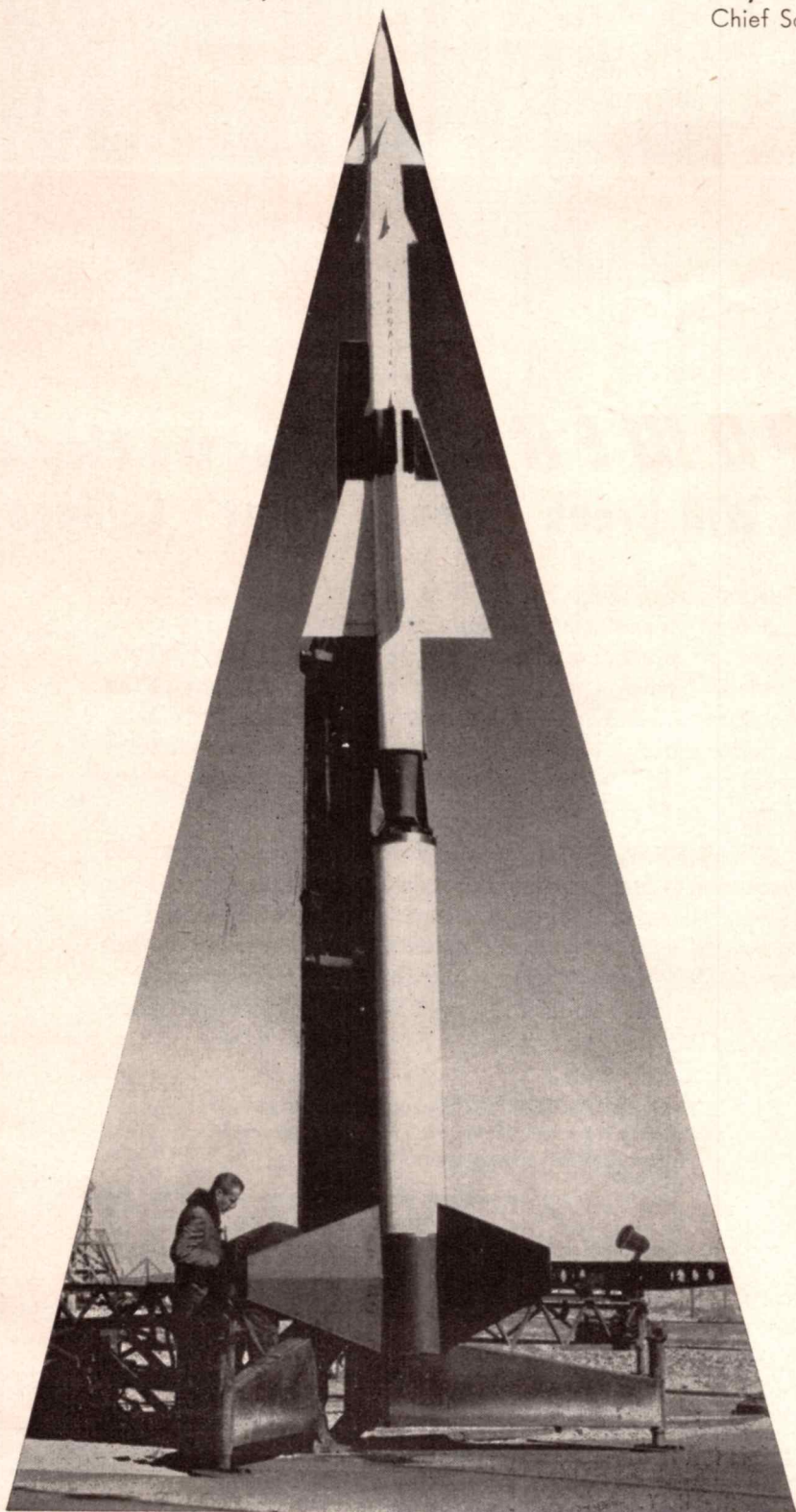
Power plant design, fuel development, and aerodynamics have progressed steadily to the point where the attainment of such goals as mentioned above was merely a matter of time and coordination.

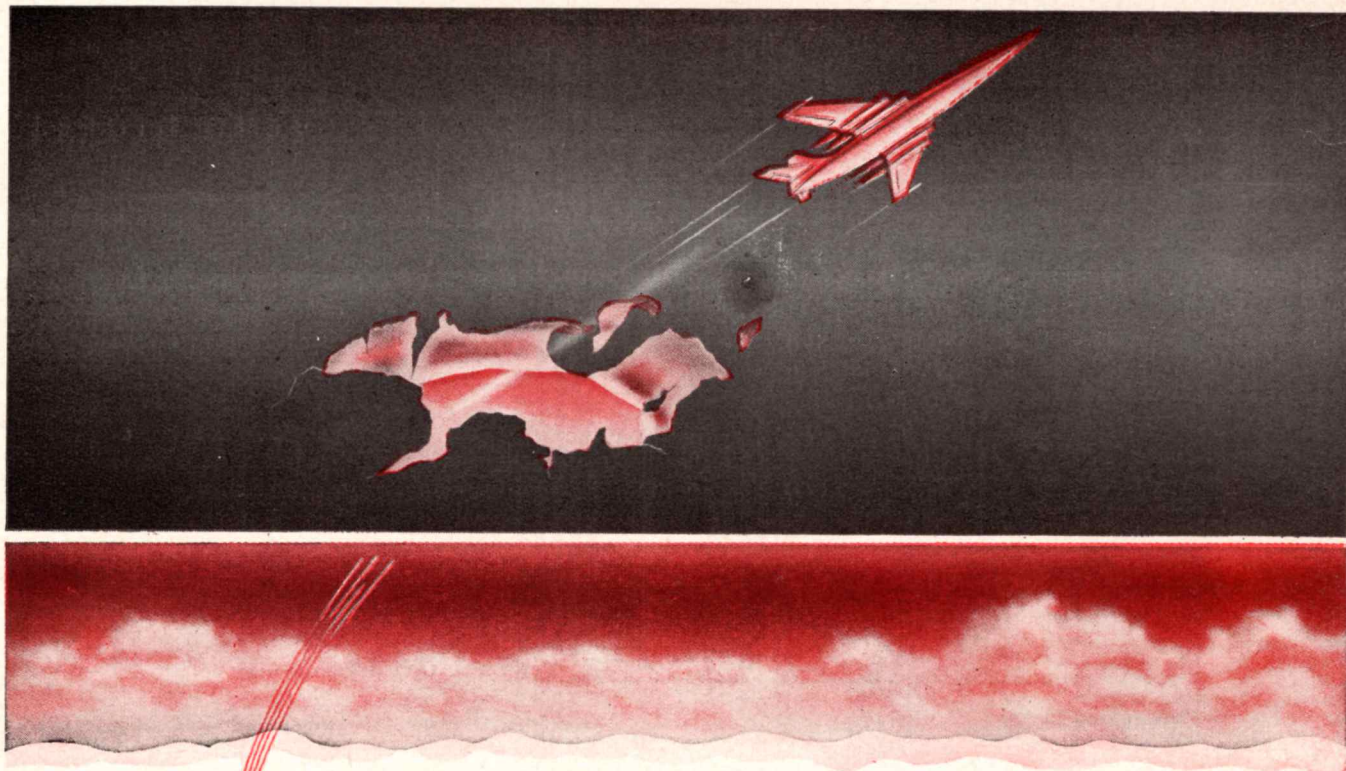
But progress in materials research has not kept pace with other fields. True, titanium and similar metals have been brought to the stage where missile and rocket fuselages are entirely practical, albeit expensive. Guidance systems, on the other hand, are being severely handicapped and retarded by a lack of suitable materials for their component development.

Let us examine the various systems, within the limits of security, and see what problems exist, and what has been done to date in their solution.

In general, missile guidance may be broken down into two categories, active and passive. In the active system, the vehicle contains some type of signal generator, such as a radar system, which sends out its own searching beam to detect the target. Having found its prey, the beam locks on the complex set of devices which guide the missile, and eventually the target is overtaken and destroyed.

The second broad system is the passive seeker. Several types have been developed, including heat-seeking and sonic amplifiers. They may best be described as units

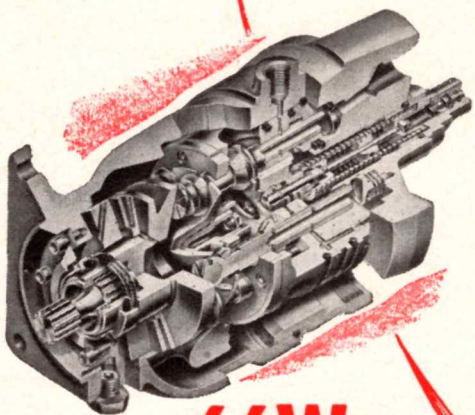




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tion system is the electronic computer. It is a very important tool in resolving the accumulation of data and performing the many calculations involved. By the use of such a device, the data can be reduced both economically as well as in time to be of practical value. The reliability of a computer is another reason for its use, for human error in calculations is eliminated.

Quick Processing

In a wind tunnel or model basin data reduction situation, quite often it is desirable to process the data in real time so that controls may be introduced as a result of data read in an actual closed loop servo. Sometimes the controls may be manual, but real time computation, or as close to it as possible, is still desirable. This type of data reduction application places the most stringent requirement on a computer, as far as data processing speeds are concerned.

In many cases the wind tunnel or model basin may have multitudes of inputs for the computer. Hundreds of pickoff points on a surface may be quite common. This creates another stringent requirement on the computer, in terms of the quantity of data that must be reduced.

As contrasted with this, an application to a single missile flight involving data reduction, where the missile is expendable and reasonably expensive, means that real time reduction is not as necessary. A larger amount of time can be spent in reducing and studying the data, since the time between flights is greater, and no control or closed loop servo system is required. There are obviously many types of applications between these two extremes.

Because measuring and recording devices are still in an early stage of development, the entire input picture to the computer is in a very confusing state of flux.

At present there exists manual automatic film readers and other devices which punch data on IBM cards. There are some tape recorders in existence and others under development.

Most organizations are attempting to put everything onto magnetic tape because it is the most rapid input medium for a computer.

As an example, our CRC 102-A General Purpose Computer with its variety of input devices, can be used conveniently with both present and future recorders. It can accept data from typewriter keyboard, punched tape of the electric typewriter, punched cards and magnetic tape. (Fig. 1).

The keyboard and punched tape are used primarily for control and entry of programs for the first time and for manual corrections.

The punched card input can be used to read decimal data punched by the various devices mentioned previously.

The data held on magnetic tape is usually grouped together with associated addressing information. These groups are called blocks of information. By specifying the location of the data (block address) the tape unit automatically finds the proper block and transfers this information to the computer. Computer information can also be recorded onto the tape by a similar block addressing procedure.

If groups of data are scattered or randomly located on the tape, the computer can call for the next piece of data desired by initiating a block search signal specifying some identifying feature of the data such as time or distance. While the tape unit moves the tape to the data, the computer can be reducing the previous set of data.

It appears that the magnetic tape input will be reasonably compatible with many of the recording systems now under development, so that future equipment using magnetic tape recording can be coupled to the computer.

Missile Data

The following summary is typical of the types of missile data now being reduced and the computations involved:

The input data to be reduced is collected in two categories; field data recorded on magnetic tape and field data recorded on photographic film and later transferred to punched cards. In the first category are:

1. Reflection Doppler Radar, frequency being proportional to radial velocity of missile.
 2. Telemetered data.
 3. Magnetic pickups. Pulses determining position of missile along track rail.
 4. Carbon rod data. Time at which carbon rods are broken during initial acceleration.
 5. Other time interval measurements.
- In the second category are:
6. Bowen film records. Position of missile in space.
 7. Askania Theodolite. Position data.
 8. Radar Boresight film. Radar jitter and target position.

The computations and outputs are:

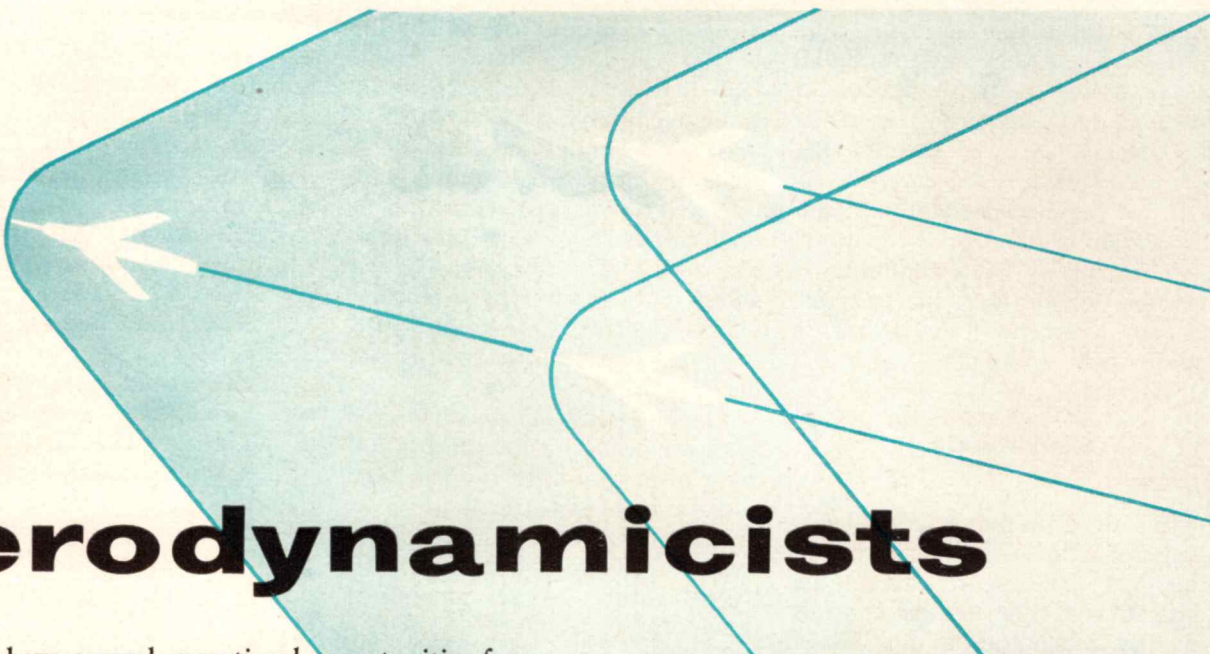
1. Checkpoint computations on Bowen film reader missile space positions.
2. Computations of camera constants, checkpoints and trajectories on a small scale from Askania Theodolite data.
3. Azimuth and Elevation of drone or missile with respect to beam center from Radar Boresight data.

Mathematical Methods

The following is a list of a few of the mathematical methods employed on the CRC 102-A which are similar to many of those used in the missile field:

1. The smoothing of observed data by:
 - a. Least square approximations by 3rd degree polynomial.
 - b. Orthogonal polynomials.
2. Computation of velocity from observed or smoothed data.
3. Solution of simultaneous linear algebraic equations by Inverse Matrix, or similar methods.
4. Solution of simultaneous differential equations.

Electronic computers are doing today jobs that yesterday were thought impossible. If this trend continues, the perfect system, mentioned above, may possibly evolve. If such is the case, it may not be strange to see, in the future, a master computer wholly controlling the data reduction system from data accumulation to the production of desired results. END



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We have several exceptional opportunities for experienced aerodynamicists interested in engineering and research aerodynamics. We also have aerodynamic assignments available in the preliminary design of new aircraft and guided missiles.

VACANCIES EXIST IN THE FOLLOWING FIELDS:

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- 3 Missile Aerodynamics** — study of missile stability problems, development of automatic stabilization devices, cruise and guidance system analysis, tactical analysis and launching studies. These are permanent positions in our well-established current and future missile programs.

The above permanent positions are available at all levels and offer excellent opportunities for advancement. Requirements include BS, MS or PhD in Aeronautical Engineering plus two to ten years of aerodynamic design experience.

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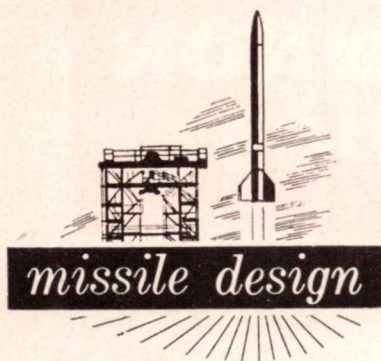
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Laborious research data reductions are speeded, improved in accuracy by new aid

ROLE OF THE ELECTRONIC COMPUTER

By J. F. DONAN

Computer Research Corporation

DATA reduction is essentially the process of taking a large quantity of raw data, then rearranging and interpreting it by mathematical formula, and converting it to a more desirable form. This resulting information is now a mathematical description of a performance which was measured by many independent observations. The application of data reduction to missiles is essentially the job of analyzing the performance of an object in motion from the information obtained from various data measuring devices.

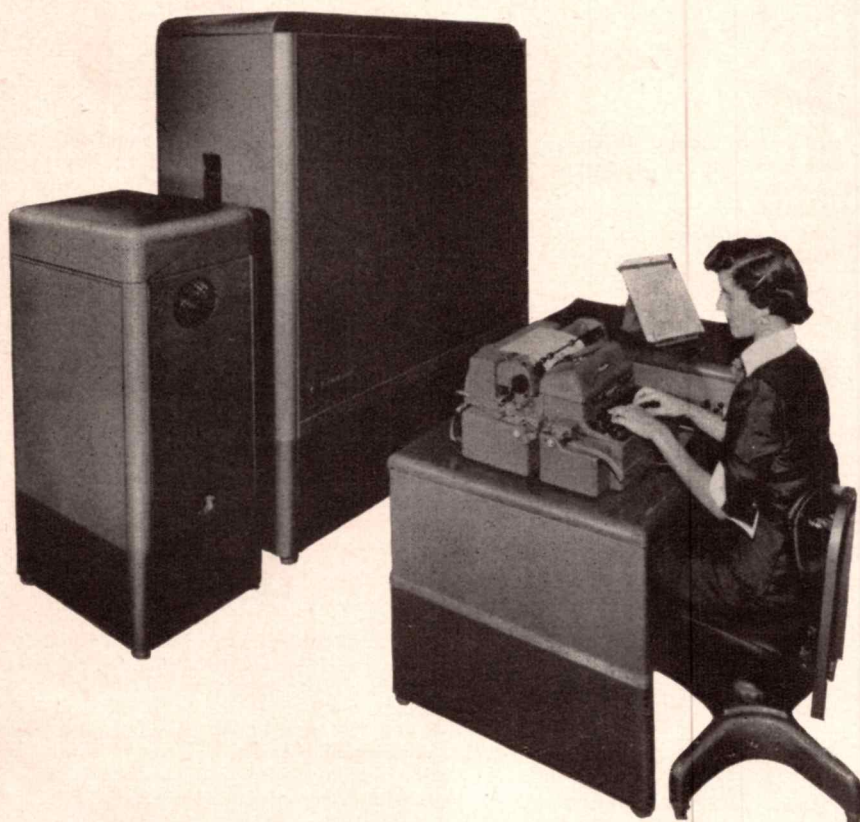
Data reduction is usually separated into classes, the division of

these classes being made as a function of the source of data. Missiles, high speed aircraft, rockets and other objects which are actually in motion are one source. Wind tunnels, model basins and other laboratory devices which simulate motion in some way are another type. Each of these could be broken down into several types according to whether the data measuring devices are moving or not.

Another classification can be made by the type of data measuring instruments used. Real time vs. scaled down measurements form one class. Automatic vs. semi-automatic or manual measuring and

recording form another class. Photographic, magnetic or other recordings on a moving object vs. telemetered or ground based photographic data could form still a third class. The various classifications are important because of the variations in requirements of the mathematical computation involved.

At the heart of the data reduc-

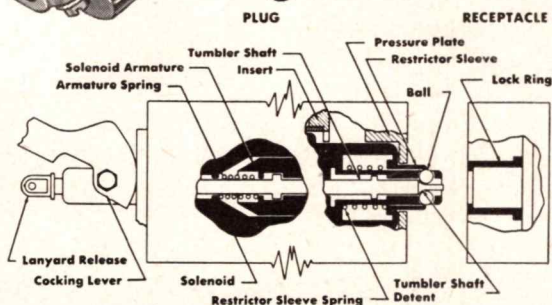
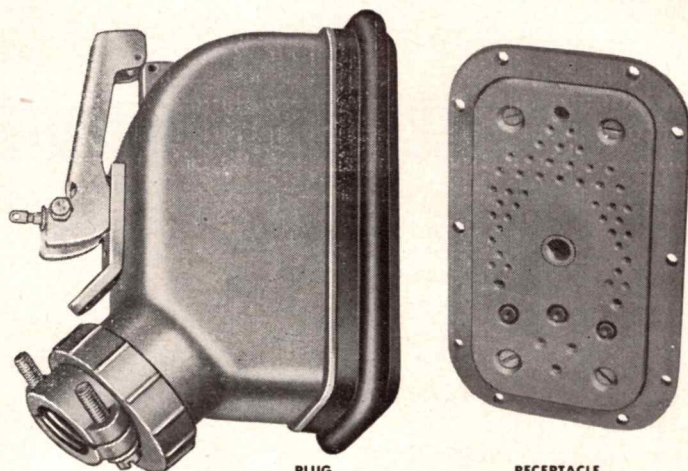


NACA research model develops thousands of test readings in flight of only few seconds

Fig. 1 CRC 102-A computer unit accepts data from typewriter, cards or magnetic tape

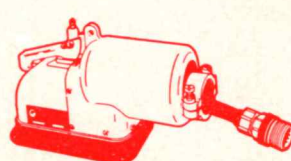
for guided missiles...

CANNON PLUGS

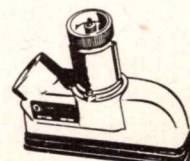


Cannon's Type GMA Plug and Receptacle, equipped with 45 degree endbell. Available either with remote solenoid disconnect mechanism or manual lanyard release. A ball-and-detent type breakaway plug, accommodating from 41 to 140 contacts, ranging in wire size from 0 to #16.

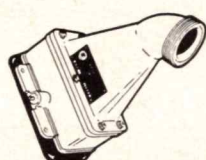
Cannon's type "GM" Guided Missile Connectors, available in more than 10 basic shell designs and a wide variety of disconnect systems, are engineered for guided missile launching under ordinary and hazardous conditions. Built for heavy service duty with shells of durable aluminum alloy and inserts of melamine or laminated phenolic, these sturdy connectors have a maximum current rating of 200a and a nominal flashover value of 5,000v, more than 22 contact layout arrangements accommodating from 8 to 140 contacts. Co-axial, thermocouple or high-current-capacity contacts are available. Many types of Cannon Plugs are used in rocket and missile components. The "GM" Series extends Cannon's policy of complete and comprehensive connector service into the launching phase of guided missile development.



GMAN type . . . ball-and-detent latch . . . lever actuated engagement . . . solenoid or manual release . . . high current contacts and 90 degree angle endbell. Two contact layouts.



GMC type . . . ball-and-detent latch . . . handwheel actuated engagement . . . remote solenoid or manual disconnect . . . equipped with 45 degree endbell. Three contact layouts.



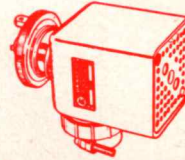
GMD type . . . sled-and-skid type connector for rack launching . . . skid-way type disconnect . . . longitudinal mounting brackets . . . 60 or 90 degree endbells. Two contact layouts.



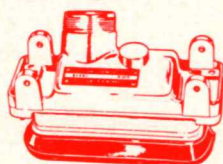
GMDA type . . . sled-and-skid type connector for rack launching . . . lateral mounting brackets . . . skid-away release mechanism . . . straight or 60 and 90 degree endbells. Six contact layouts.



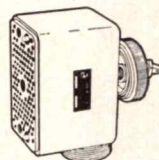
GMDD type . . . sled-and-skid type connector for platform launching . . . straight endbell . . . longitudinal mounting ears . . . 22 size 14 contacts. One contact layout.



GME type . . . ball-and-detent type latch . . . handwheel engagement . . . manual release only . . . handwheel equipped with ears for clevis . . . 90 degree angle endbell. Seven contact layouts.



GMJ type . . . sled-and-skid type connector for platform launching . . . manual fall-away disconnect . . . mounting ears fitted on rear . . . 30 degree angle endbell. One contact layout.



GMK type . . . ball-and-detent latch . . . handwheel engagement . . . with or without ears for clevis . . . manual release only . . . 90 degree angle endbell. Two contact layouts.



GME type . . . ball-and-detent latch, handwheel actuated engagement, manual lanyard release only. 90 degree endbell. One contact layout.



Refer to Dept. 103

CANNON ELECTRIC COMPANY, 3209 Humboldt St., Los Angeles 31, California. Factories in Los Angeles; East Haven; Toronto, Canada; and London, England. Representatives and distributors in all principal cities.



CANNON ELECTRIC

In addition to the "GM" Series, Cannon Types "AN", "K", "DPD", miniature connectors, and the J06 are used for missiles and jettisonable equipment. For an overall survey of these, request your copy of the "Cannon Plug Guide". For complete engineering data on the "GM" rocket launching connectors request the "GM" Bulletin on company letterhead.

eter of the body, but that does not lead to an efficient combination. Some gun fired missiles have retractable fins that spring out after the missile has left the gun. The springs must throw the fins out really quick, for there is not much time, and the missile has to be stable as soon as possible.

A rigidly mounted stabilizing surface has to be in rear as with every arrow, etc., for the reason that also in supersonics a positive incidence produces a pressure on the incidence side. With missiles having jet drive the rear location may be inconvenient on account of the high wall temperatures of the tail and because there may not be enough room to mount the fins safely. The tail position may be quite impossible with rear jet arrangement if the fin incidence is controllable. There just is not room for both, fins and jet. A surface at the nose is not stabilizing but destabilizing by its mere presence. But if it has a controllable incidence, stability may be provided by fin control, and the destabilizing may be kept small by a small size of the surface. The front surface is then used for stabilizing in connection with a kind of automatic pilot which turns the front fins quite fast into the positions needed. In other words the missile is stabilized by the skill and swift action of the automatic pilot. The scheme works, but the arrangement is more complicated than a rigid fin. It requires electronic gear, and that may get out of order. Our confidence in the reliability of such electronically controlled front stabilized is somewhat shaky. A pilot who has to fire missiles to the front of his airplane feels more comfortable if the missile is stabilized by

rigid rear fins than by an electronically controlled front fins.

Straight Wings

These are rarely used with supersonic missiles, but the unswept trailing flaps act similar to unswept airfoils. If the wings are plane and of zero thickness, their theory is simple. The air is then deflected from the undisturbed direction of motion into the airfoil direction, said deflection taking place along pressure wave forming the Mach angle μ with the direction of motion. The perturbation velocity, that is the difference of velocity in front and behind the pressure wave, must be at right angles to this wave. Hence the ratio of the normal perturbation velocity component (normal to the undisturbed velocity) to the streamwise perturbation velocity component is equal to the tangent of the Mach angle. In view of the Bernoulli equation

$$dp = -\rho v dv$$

the pressure increase and decrease dp respectively on the bottom and top of the airfoil will be as follows

$$dp = V^2 \rho / 2 \alpha \tan \mu$$

The lift slope is therefore equal to

$$\begin{aligned} dC_L/d\alpha &= 4 \tan \mu \\ &= 4/\sqrt{M^2 - 1} \end{aligned}$$

The arguments imply some simplification, a two-dimensional flow was primarily implied, and the lift slope is approximate only. But it furnishes the correct order of magnitude of the pressures and lifts occurring with such unswept wings.

Body-Wing Interference

The interference of the missile body on the wing is large because the wings are relatively small compared with the body diameter. The

inclined body blocks the flow of the air. The air has to go sideways around the body. The sidewise flow hits the wings and increases their angle of attack. This is not a small matter; adjacent to a cylindrical body outside of its boundary layer the angle of attack of the wings is practically doubled. We have to remember that the basic requirement of supersonics is a small angle of attack. So this increase of the angle is of serious concern to the missile designer.

If anything can be done about this it should be done. It would be well worth while to take inconvenience into the bargain. But so far, no means have become known to remedy this situation. In all missiles released so far the bad interference effects between wing and body have been accepted.

Spinning

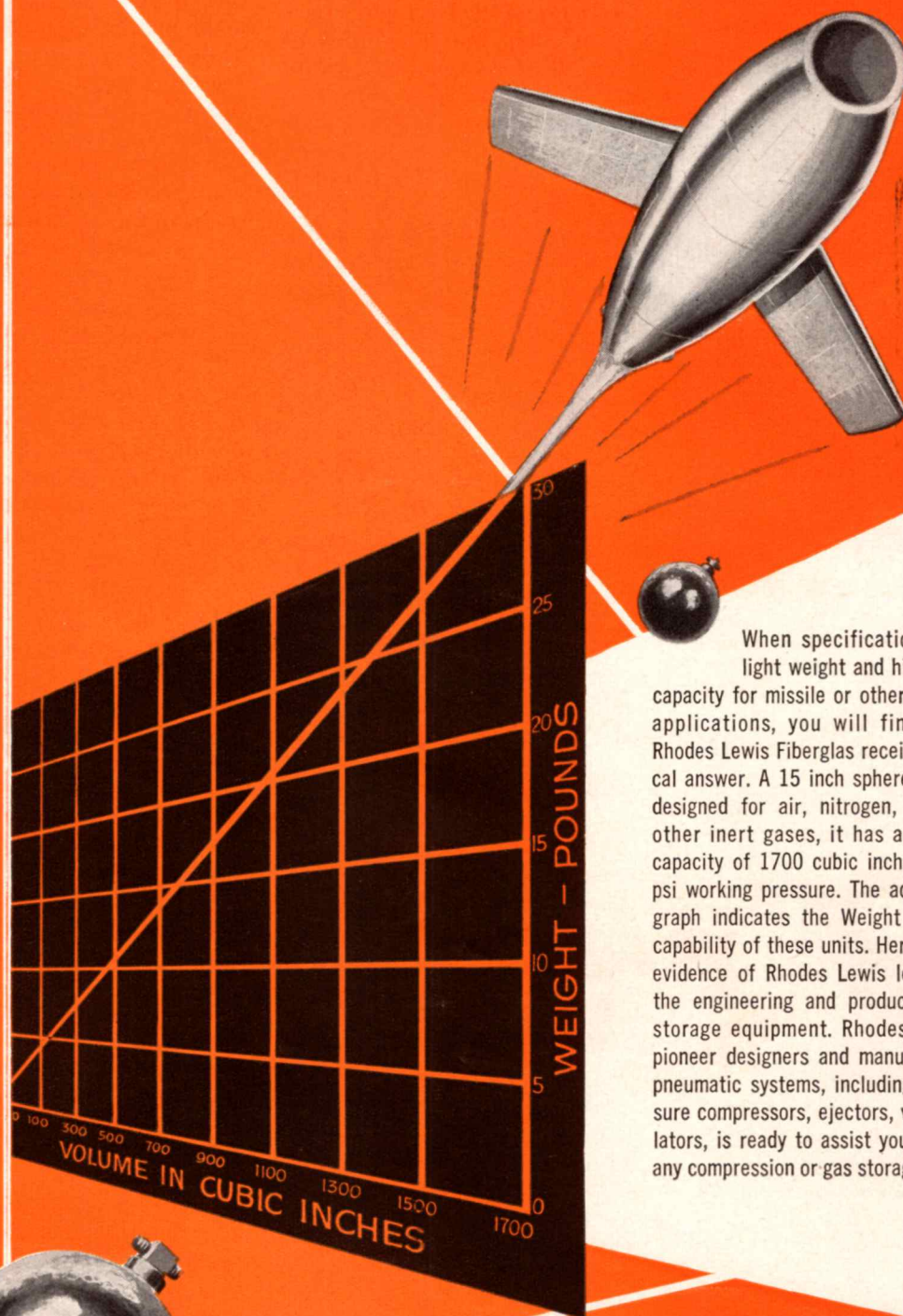
Every fin stabilized missile tends to do some spinning. It rotates about its axis because it is not practically possible to make the missile truly symmetric. The fins are never exactly parallel, and even if they were the missile may still spin if the surface of the missile is unequally smooth. Spinning may interfere with the proper functioning of some instrumentation within the missile. Special anti-spin devices may be required. A moderate rate of spin is considered desirable by some designers because it evens out the effects of the unsymmetry of the missile. It thus reduces the dispersion of the missile. The motion of a spin-stabilized missiles inclined relative to its flight path produces aerodynamic forces of its own, called Magnus forces. They act sidewise, like a lift or sideforce, proportional to the plane of inclination. The Magnus forces are often of considerable magnitude, and change the stability behaviour of the missile. By virtue of following quite different laws than the ordinary aerodynamic forces they often work profound changes on the character of the missile motion. A missile otherwise stable may become unstable under the action of the Magnus forces. This has often happened. The Magnus forces are therefore unpopular in missile design.

END

First photograph of new Lockheed P2V-7 shows revised nose, cabin, ASW tail stinger unit. New model features light weight, improved performance



WEIGHT COUNTS



When specifications call for light weight and high pressure capacity for missile or other expendable applications, you will find the new Rhodes Lewis Fiberglas receiver the logical answer. A 15 inch sphere, especially designed for air, nitrogen, helium and other inert gases, it has a volumetric capacity of 1700 cubic inches for 3000 psi working pressure. The accompanying graph indicates the Weight vs. Volume capability of these units. Here is striking evidence of Rhodes Lewis leadership in the engineering and production of gas storage equipment. Rhodes Lewis Co., pioneer designers and manufacturers of pneumatic systems, including high pressure compressors, ejectors, valves, regulators, is ready to assist you in meeting any compression or gas storage problems.

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must be operated by a robot or by some long distance control gear, electronically. Such flaps or control surfaces have to take care by themselves of all their control forces. They cannot act as mere trigger members and throw the lift or else side force on the stationary surface in front of them, like with subsonic airplanes. This would require upstream travelling acoustic waves which just cannot occur. Thus the hinge moments and hinge loads of the control surfaces are large. The chief advantage of the flaps of conventional airplanes is absent. The entire wing may as well rotate about a spanwise axis. This is indeed preferred by some designers, but is structurally less convenient than trailing flaps.

Swept Wings

Slightly supersonic airplanes are ordinarily equipped with swept back or arrow wings. Swept for-

ward wings have also been recommended. Their leading edge and trailing edge are nearly parallel. A swept wing extending with infinite span from left to right would be nearly equivalent to the same wing flying at right angles to its spanwise extension with a velocity equal to the component of the flight velocity normal to the leading edge. That may be a subsonic velocity. Hence, such wing cannot have any wave drag at all. Any wave drag requires supersonic speed in essence and effect. With a finite wing span the argument is weakened near the wing tips, but on the whole the airfoil would have local wave drag only near the tips and the total wave drag would be small.

Swept wings are not equally popular with supersonic missiles. In the first place the wings are usually small when compared with the bodies and with the chord, the

wings are all wing tip, and the local wing tip wave drag would prevail over the entire wing. Furthermore the large Mach number would require an excessive sweep angle, and the wing tip may then as well be connected with the body, whereby the wing would be transformed into a Delta wing. Such structural connection is badly needed because the large sweep-back is structurally unfavorable, it implies not only large bending moments but also torsion of the wing.

The swept wing is also inconvenient for a trailing flap. Nor is the swept wing convenient for being rotated as a whole on account of the large hinge moment. The wing is subject to flutter and structural failure; it is not popular because it is not practical for high speed missiles.

Stabilizing Surfaces

Stabilizing surfaces or fins are necessary for non-spin-stabilized missiles, in the same manner and for the same reasons as with airplanes and airships. The stability problem is more severe because the center of pressure travels not only with a change of the angle of attack but also with a change of the Mach number. Also, the wings in front of the fins send out concentrated compression waves which may interfere with the rear fins. This danger is overcome by some designers by placing the fins in a 45° relation to the wings.

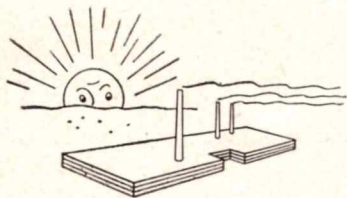
A projectile shot out of a gun is not often called a missile but it may be fin stabilized, not spin stabilized like an ordinary shell. Fin stabilized projectiles have greater length and smaller cross-section than spin stabilized projectiles. They have thus a smaller drag for equal weight and can therefore be shot through a larger distance. Their axial moment of inertia is too small in relation to the cross-wise moment of inertia for spin stabilization. Fin stabilized projectiles have much in common with self starting missiles. The gun barrel creates a serious problem because the fins have to be accommodated within it. Missiles can be stabilized by means of fins not extending beyond the largest diam-



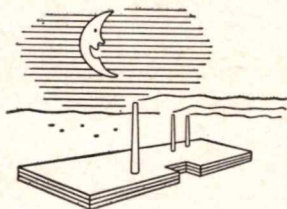
New Sikorsky XHSS-1 special anti-submarine warfare helicopter is cross between H-19 and twin engine HR2S-1



Kaman HTK-1 helicopter is powered by two Boeing 502-2 gas turbine engines for test. Earlier Kaman K-225 tested a single Boeing unit



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on correct and sound basic principles. Under all erratic features and unevenness and sudden contrasts of the supersonic flows there are hidden quite simple basic principles transcending the irregularities in detail. These principles are by now well understood. They are hardly controversial, it is believed that all experts will agree with what follows. Looking the different basic considerations over one after another is quite entertaining. Naturally such discussion concerns the lift or sideforce, and the drag of the missile body and its appendages, the different portions of which should be separately considered and the reasons for the different arrangements of the control surfaces and wings and their forms often adopted.

Maximum Supersonic Lift

In certain guided missile types launched against stationary or slowly moving targets, the maximum lifting capacity of the body and wings is of secondary importance; but if the missile is to be launched against fighter aircraft, for instance, then the maximum

this lift cannot be fully utilized because it would be associated with too much drag at the high angle of attack of the body. Hence wings must be provided that will produce sufficient lifting capacity in turning with the longitudinal axis of the body almost parallel to the flight path. Sometimes the desired maneuverability and control is obtained by rotating the wings relative to the body. In this way the effect of the rotational inertia of the body is minimized, and the body drag is kept low.

Body Shape

We understand by now that the body has to have a slender contour and a sharp and pointed nose. The exact body shape does not seem to matter much or to be critical or of particular importance. Cylindrical rear bodies combined with ogive front bodies having circular arc contours, the entire surface having axial symmetry, are popular. They are relatively easy to draw, to describe, and to manufacture, and seem to be as good as anything else. In supersonics, the shape of concave surfaces is critical

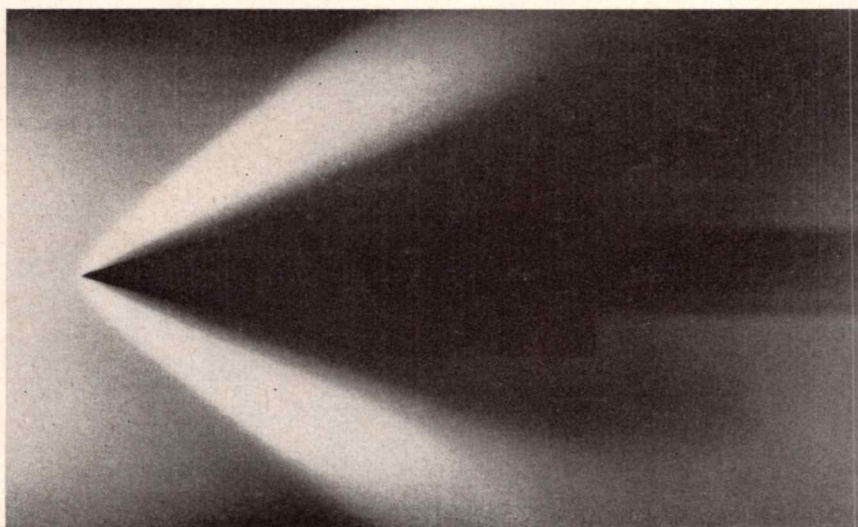
necessary for jet drives, but even artillery shells having no drive at all have a flat base. The reason is that the danger of excessive pressure in front is much larger than the danger of suction in the rear. The front pressure must be prevented from building up to the maximum it is capable. The suction in rear cannot possibly fall correspondingly low. Theoretically it cannot fall below the absolute vacuum of the physicist. Actually that vacuum is never even reached. That partial vacuum prevailing at the rear flat base is relatively insignificant when compared with the large front pressures theoretically possible. Thus the wave drag is not as harmful in rear as it is in front. It would not pay to reduce it further by streamlining requiring additional surface associated again with additional friction drag. It is more economical to use up all streamlining surfaces available for reducing the front wave drag pressure, and to accept the rear vacuum, called base pressure however it may come out.

The Delta Wing

The delta wing has gently swept back straight leading edges and an unswept trailing edge. The leading edges are ordinarily straight because sweeping them less at one place and more at another would do more harm than good. Of course, straight edges are convenient in construction. A very small curvature would not do any harm, but it is just useless and inconvenient. The large sweep back is in keeping with the necessity to deflect the air gradually, so that the produced pressure wave may be as weak as possible.

Sweep is not necessary at the trailing edge. The trailing edge has only effect on what goes on behind it. It cannot have any effect on the wing drag because all acoustic effects are swept downstream in view of the large supersonic velocity of motion. Any noise generated at the trailing edge could not be heard at any point of the airfoil. No effect or flow modification can therefore be caused on the wing by the abrupt trailing edge.

The abrupt unswept trailing edge is also convenient for the mounting of control flaps. They



Pattern of bow shock cone over pointed nose of missile shape at high supersonic speed

lift is of genuine concern. For it is indicative of the highest practically usable lift. In the latter case the problem is to obtain a sufficiently high lift to give the desired turning radius without excessive drag and propulsive power. In some cases the body alone of the supersonic missile would give sufficient lift; but

and the finest details are of great importance. But the shape of convex portions of the surface is not critical.

The very rear of the missile body may be slightly streamlined, then called boat-tailed. The body terminates always with a flat base surface, quite abruptly. This may be

THE designer of supersonic missiles must, of course, keep his eye on the missile performance, on the speed, altitude, and the range obtained. But the hardest problems are stability and controllability. For what good does excellent performance do, if the missile cannot fly straight and in proper manner, and will never get to its destination? And these desirable flying properties are difficult to achieve because the air forces and, particularly, the center of pressure vary not only with the angle of incidence but with the Mach number—with the speed of advance.

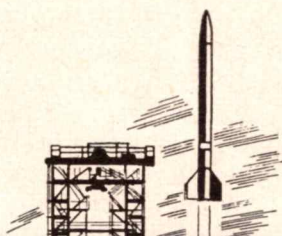
The designer has not enough to go by to predict the aerodynamic properties of the missile with suf-

ficient precision before it is built. That is so for quite a variety of reasons. Theoretical aerodynamics alone is inadequate, and supersonic aerodynamics is even more difficult than classical airplane aerodynamics. Laboratory tests such as wind tunnel tests are by no means as accurate as desired. Flight tests, although essential for various stages of development do not always yield sufficient information for remedial measures after failures, because the number of available radio channels for communicating data from the missile to the ground is usually limited, and recovery of the missile without damage may be impractical.

The aerodynamic layout of the

air frame is furthermore complicated by the erratic nature of supersonic air motion and of the pressure distribution created by it. Different kinds of waves, focus effects, shadow effects, and pressure concentrations combine to make the flow picture confused and unpredictable. The body appendages such as wings and fins are comparatively small, and the interference effects between body and fin are large and stand in the way of prediction. Thus, any precise dimensioning and detail layout of a supersonic missile is indeed a difficult art, a struggle with uncertainty.

It is therefore particularly important that a trial lay-out be based



missile design

ATTAINING STABILITY AND CONTROL

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Catholic University

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NACA test missile at Wallops Island rocket station determines stability of delta cruciform tail



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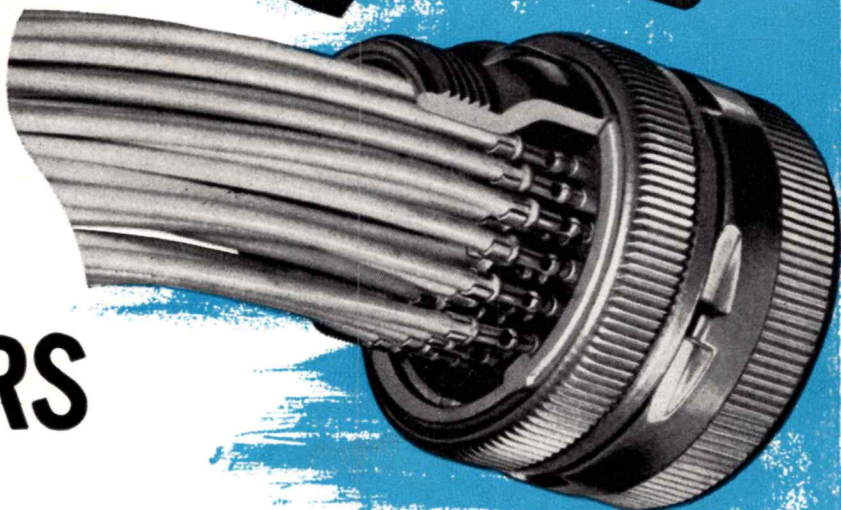


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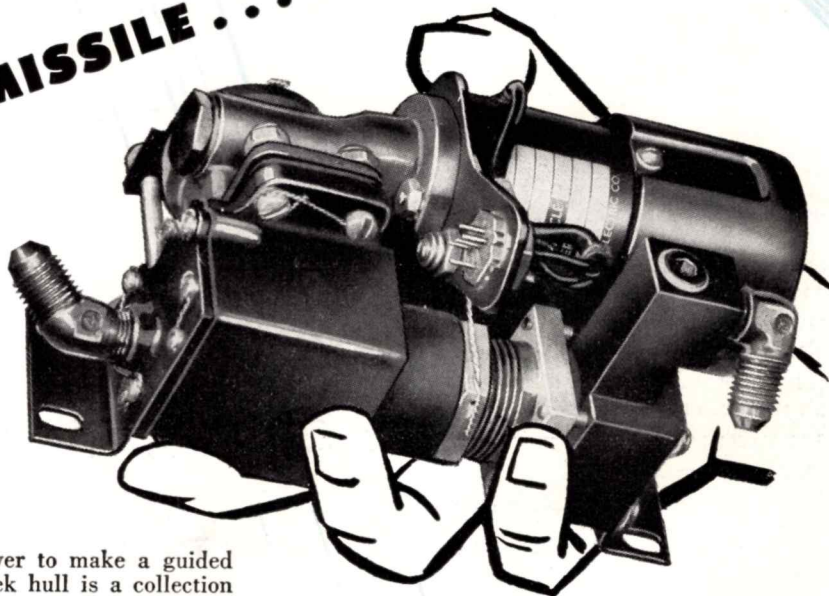
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